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THE FISH RESOURCES OF THE OCEANS

compiled and edited by

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This report is dedicated to the memory of Dr. W.M. (Wib) Chapman,
in recognition of the support and assistance he gave to this study.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
me, July 1970

PREPARATION OF THIS DOCUMENT

This report has been prepared in the Fishery Resources Division, Department of Fisheries, FAO, in collaboration with regional fishery bodies, and individual scientists, to provide a background against which fishery development can be planned, and possible need for research and management noted. Throughout the preparation of this study, advice and where necessary guidance was received from the Advisory Committee on Marine Resources Research.

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In addition to the authors named above many scientists have helped, by supplying data, advice and comments, in the preparation of this document. Statistics have been provided by Mr. L.P.D. Gertenbach and the staff of the Fishery Statistics and Economic Data Branch, FAO. The bibliography has been checked by Miss G.A. Seave. The preparation and final typing were done by Miss D. Spencer and Miss F. Zodda.

The catches of fish from the oceans of the world have been increasing at a rate of some 7% per year (doubling every 10 years), and reached 50 million tons in 1967. In some areas and for some stocks, e.g. the larger demersal fish in the North Atlantic, it has long been clear that catches have approached the level of the total potential production of the area.

r, the relation between catches and potential is less clear for the oceans as a whole. Various estimates of potential have been made ranging from 55 million tons up to 2,000 million tons. Much of this difference can be accounted for by differences in the types of organisms included - all animals, excluding the smaller zooplankton, or all fish, or all fish harvestable with present techniques. Meaningful estimates should therefore take into account the detailed composition of the potential catches.

Such a world appraisal of fish resources has been one of the long term objectives of FAO's Department of Fisheries (and earlier the Fisheries Division) for many years, but staff and other facilities were lacking for its implementation. These became available when detailed information on resources was required for preparing FAO's Indicative World Plan for Agricultural Development (IWP) (agriculture in this sense includes fisheries), and early drafts of the sections of this report were used in preparing the fisheries chapter of the IWP study.

The present report is intended to serve two main purposes: first, to provide basic information on resources to indicate possibilities for development of new fisheries and to facilitate the planning of such development; second, to provide an early warning of the need for conservation and management when catches approach the potential limit of the resource.

Inevitably, in many areas the information available is not sufficient to produce accurate estimates, and a third major objective of this study is the encouragement of research and the collection of basic data, such as catch statistics, ecological data and the characteristics of the population dynamics of marine organisms that are existing or potential objectives of exploitation. From these more accurate and realistic estimates can hopefully be derived.

1. PROCEDURES

The general procedures followed were developed following a meeting of a small advisory group of experts (D.L. Alverson, A.S. Bogdanov, D.H. Cushing, H. Kasahara, W.E. Ricker and M.B. Schaefer), held in Rome in December 1966. The resources were considered separately for each sea area - using for convenience the sea areas used in FAO's Yearbook of Fishery Statistics. Close cooperation was maintained, where appropriate, through the regional bodies (ICES, ICNAF, etc.). A first draft for each area was prepared by a consultant or an FAO staff member, and circulated to the regional body (if exiting) and to individual scientists known to have a major interest in this area. On the basis of comments received revised versions were prepared.

Certain resources were treated separately on a world, rather than a regional basis, since their study involved rather specialized problems. These are the crustaceans, the molluscs (excluding cephalopods) and the resources of the open oceans. Seaweeds have been excluded from the present report, though studies on these resources are being made, and it is hoped to include them in a future version.

The value of this report and the reliability of the estimates included in it, have been very greatly increased by the very numerous and detailed comments received on the early drafts. It is not possible to acknowledge here individually all those who have spent considerable time and trouble in preparing comments, though special mention should be made of the original advisory group, and of W.M. Chapman, who, though unable to attend that meeting, has taken a very close interest in the studies as they progressed.

To enable as quantitative and complete a summary as possible of the total world resources to be produced, actual figures have been produced wherever possible as estimated of the potential catches from individual stocks, even when the information is very scanty. Too much attention should therefore not be given to the precise values of many of the estimates.

These estimates are also of the sums of maximum potential long term yields from individual stocks concerned, i.e. the yield from each stock that would be obtained under average environmental conditions, with the pattern of fishing adjusted to maximise the yield from that stock. The actual yield, even under steady fishing, will vary from year to year, e.g. due to variable year-classes. Also, it is most unlikely, in an area where several stocks exist, that the overall pattern of fishing will be such that the maximum yield is taken from each stock. Among the heavily exploited stocks, even with good management, some are likely to be under-fished (the yield would be increased by greater fishing), and othersover-fished. Also little attention has been paid to the practical possibilities of harvesting the resources. Even the groups of fish commonly harvested there are some species, e.g. dabs in the North Sea, of low market value, or with scattered distribution, whose capture is not economically attractive. The figures must therefore be considered as being generous estimates of the catches from each group of fish that might be achievable in practice.

Culture of fish and other marine animals is not considered in detail. Such culture is essentially of two kinds - culture making use directly of the natural production, e.g. oyster culture, and that based on the intensive rearing of high priced animals, dependent on the external supply of food. The former type is largely confined to molluscs, and is discussed further in that section. The latter type is little more relevant to the use of the natural resources of the sea than the intensive rearing of chickens, or freshwater catfish. These have increased the demand for fish meal, and hence stimulated the use of previously little exploited resources such as the Peruvian anchovy. Intensive culture of such animals as lobster, shrimps, yellowtail, plaice, sole, etc., will presumably increase the market for fish meal, especially as the proportion of fish meat in their diet is likely to be larger than for chickens. Such culture must therefore be taken into account when estimating the timing and development of the exploitation of natural fish stocks, but does not affect the magnitude of the potential natural harvest.

2. METHODS

Wherever possible assessments were made using the normal methods for exploited populations, using catch and effort statistics, length and age composition data, etc. These, however, could cover only a fraction of the total potential. For other stocks other methods had to be used, based mainly on the estimation of the biomass of the unexploited stocks.

Three methods of assessing unexploited stocks, in semi-quantitative manner were used:

(a) exploratory fishing. The capture of fish by normal or modified types of commercial fishing gear;

(b) egg or larval studies. The capture of the early stages in plankton nets;

(c) echo surveys.

Exploratory fishing has the advantage that the data are immediately available in a suitable form for developing the commercial fishery. It is particularly useful for trawl surveys for demersal fish, but not so good for pelagic fish, and squid, where the most suitable gear may not be known, and if known is even less quantitative than bottom trawls.

Echo surveys are at present not generally quantitative (though methods are being developed), nor do they provide identification of species; fishing combined with echo surveys could remove both these disadvantages, and seems the most promising method.

Egg and larval surveys are expensive, take a long time for detailed analysis, and provide only a limited accuracy for quantitative estimates. A large quantity of material is, however, already in existence, and analysis of such data already collected for other purposes can provide rough estimates relatively cheaply.

A fourth method used for qualitative estimates was the inspection of the gut of large predators (fish, squid, birds, seals, toothed whales) to provide crude information on the distribution and relative abundance of the smaller fish species.

The estimates of biomass were used, together with estimates of the natural mortality, to derive estimates of potential annual yield as follows:

In the simple Schaefer (1954) model, the maximum yield (C_{max}) is taken when the biomass (population) is half the virgin biomass B_0. If it is then assumed that at the optimum point, the fishing mortality, F, is equal to the natural mortality, M, then $C_{max} = F \times (\frac{1}{2}B_0) = \frac{1}{2} M B_0$. While the real fish stock will not follow the formula precisely it is likely that some of the deviations will compensate each other. Thus the greatest yield may be taken at a level rather less than half the unfished stock, but at the same time F may be rather great than M.

Alternatively, writing

$$C_{max} = X M B_o$$

where $X = \frac{1}{2}$ in the model above,

X can also be expressed in terms of the biomass B_{max} and fishing mortality F_{max} under conditions giving maximum yield,

i.e. $C_{max} = F_{max} B_{max}$

or $$X = \frac{C_{max}}{M B_o} = \frac{F_{max}}{M} \cdot \frac{B_{max}}{B_o}$$

and this can be calculated on the basis of other models, e.g. the Beverton and Holt constant recruitment model. The actual value of X will depend on the size of first capture - or strictly, c, the ratio of size of first capture to maximum size, and the ratio of natural mortality, M, to the growth coefficient, K. The results of the calculations, using for simplicity the yield tables of Beverton and Holt (1964) are given in Tables 1 and 2. Table 1 gives the results obtained if the size of first capture is not changed, the biomass being calculated from this size upwards; Table 2 gives results if size of first capture can be adjusted to maximise the catch.

The calculated values of X, in Table 1, range from 95% to 17% which is a wide but perhaps not entirely useless range (the biggest error in taking X = 0.5 is by a factor of 3). These extreme values occur at the edges of the table, especially at rather unreasonably high or low values of c, the length at first capture expressed as proportion of the maximum length, and more likely values of c range from 30% to 70%; for these, the extreme values are 26% to 78% (68% excluding the highest value of M/K).

Alternatively the size at first capture may be variable; the greatest yield will be determined from Table 2, but the virgin stock needs to be defined. Three measures have been used - the biomass at zero fishing for c = 0, 0.40 and 0.70; the first is an upper limit to what could be considered as the fishable stocks, which normally will exclude fish below some size. Usually, fish recruit to the fishable stock at a size corresponding to a value of c between 0.40 and 0.70. The maximum yield (for any combination of size at first capture and amount of fishing) was therefore expressed as a percentage of M times the unfished biomass of all sizes of fish, or or fish above 0.40 or 0.70 of the maximum length. These are given in Table 2.

Table 1 - Maximum sustainable for given sizes at first capture, expressed as a percentage of M times unfished biomass

c	M/K					
	0.25	0.75	1.25	1.75	2.50	5.00
.98	91	92	93	95	94	94
.90	78	80	83	85	87	90
.80	64	66	70	74	78	84
.70	56	53	57	62	68	78
.60	50	44	46	50	56	69
.50	46	38	38	39	44	59
.40	43	33	32	32	34	47
.30	40	30	27	26	27	34
.20	39	27	24	22	22	24
.10	37	35	31	19	18	17

Note - K = coefficient in von Bertalanffy growth equation

Table 2 - Maximum sustainable yield for any value of size at first capture ~~expressed as a percentage~~ of M times the unfished biomass of fish above a certain size

Limiting length (% of max)	M/K											
	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00	2.50	3.00	4.00	5.00
70	66	58	55	55	58	61	(63)	(65)	(69)	(72)	(78)	(80)
40	64	52	46	43	41	40	39	38	38	38	41	47
0	64	52	46	42	39	37	36	35	33	31	29	28

(For large values of M/K the greatest yield is taken at a value of c less than 0.70, and for these values the entry for c = 0.70, enclosed in brackets, is the greatest catch for c = 0.70 expressed as a percentage of M x unfished biomass.) Except for the bracketed figures for the large size at first capture, the values only vary over quite a narrow range. The maximum yields used here are probably slight over-estimates of the greatest yields that could be obtained in practice since they are based on eumetric fishing, at high levels of effort. Probably a value of 0.5 would be close to real value, i.e. given an estimate of unfished biomass and natural mortality (equal to total mortality in the unexploited population) then a first estimate of the maximum yield is:

$$Y_{max} = 0.5 \times M \times B_o$$

and this has been used in the following sections to estimate the potential yield when an estimate of biomass of the unexploited stock is available.

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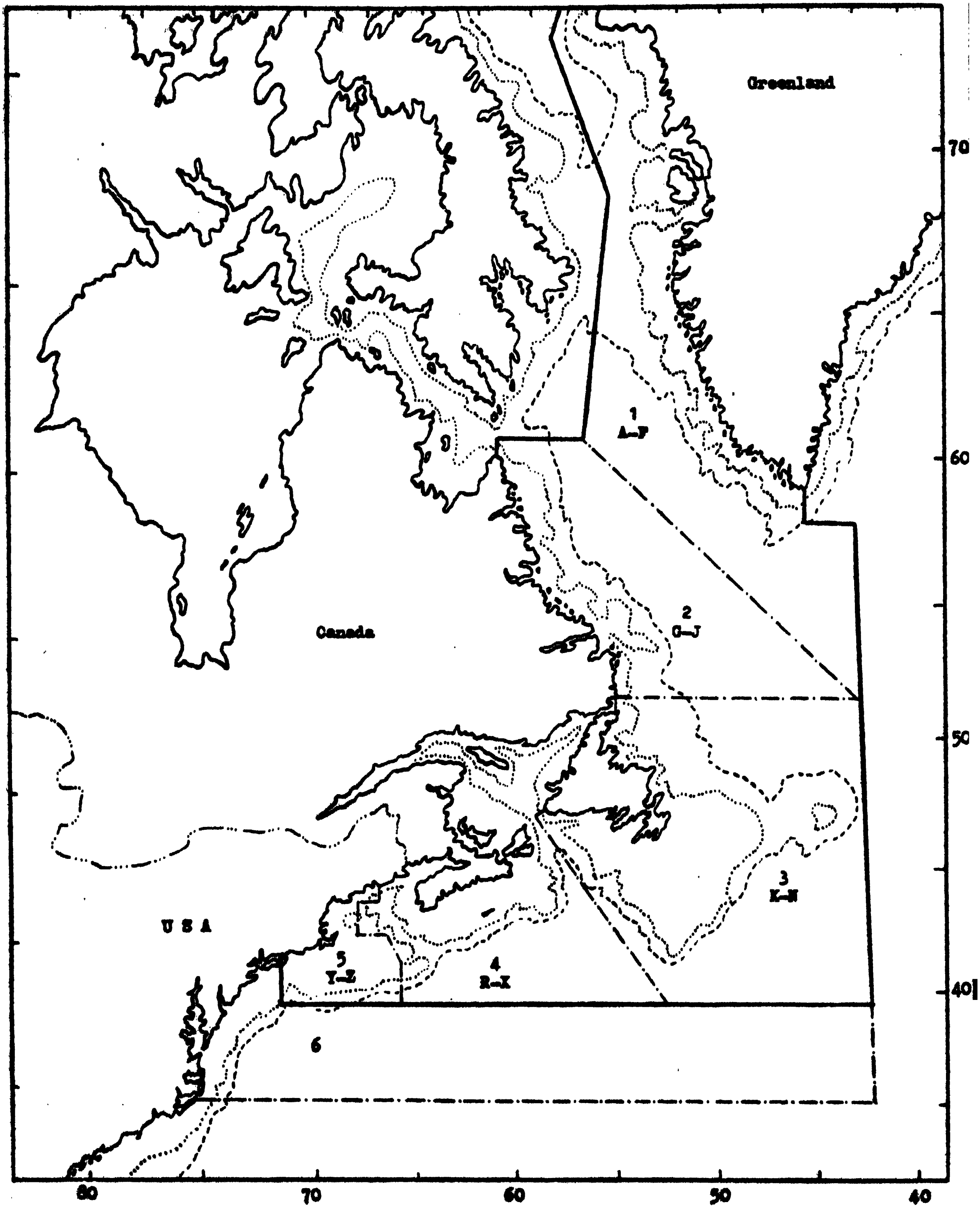

A - NORTHWEST ATLANTIC

Depth contours at 200 and 2,000 m

1. TOPOGRAPHY

The main part of the area is the concern of the International Commission for the Northwest Atlantic Fisheries (ICNAF) but it is convenient also to include the area south of the Commission area south to 35°N (approximately Cape Hatteras), i.e. sub-area 6 of ICNAF. The region is divided into six sub-areas as follows (in brackets the approximate area of shelf, down to about 200 m):

1. West Greenland (85,000 km^2)
2. Labrador (ca 100,000 km^2)
3. Newfoundland (490,000 km^2)
4. Nova Scotia and Gulf of St. Lawrence (310,000 km^2)
5. New England (185,000 km^2)
6. Middle Atlantic (90,000 km^2, excluding semi-enclosed areas such as Delaware Bay)

The figures for sub-areas 3, 4 and 5 are taken from Graham and Edwards (1962). That for sub-area 1 is rather greater than the area down to 200 m, to include all depths inhabited by cod, as suggested by Horsted. In other areas also catches are now being taken below 200 m, though the greater part of the catch, and probably also of the fish production occurs in water shallower than 200 m.

2. HYDROGRAPHY

The main features of the hydrography of the ICNAF area have been described by Hachey, Hermann and Bailey (1954). Accounts of the year to year fluctuations in these features can be found in the National Research Reports published in the ICNAF redbooks, the Annales Biologiques published by ICES, and the Annual Reports of the International Ice Patrol Service (US Coast Guard Bulletins). Since Hachey, Hermann and Bailey published their monograph two international surveys have added considerably to our detailed knowledge of the physical and chemical oceanography of the Northwest Atlantic. In 1957-8 during the International Geophysical Year (IGY) a survey was made of the Polar Front region of the North Atlantic Ocean. The main findings have been summarised by Dietrich (1964 and 1965). Later, in April-July, 1963, ICNAF carried out the NORWESTLANT Surveys which allowed three quasi-synoptic pictures to be obtained of the Irminger and Labrador Seas including the Denmark and Davis Straits. The results of these surveys have been published by ICNAF in its Special Publications series.

The dominating oceanographic feature is the close juxtaposition of warm and cold current systems. The Gulf Stream system is the source of water of high temperature. It enters the ICNAF area from the south [T_0 = 15-24°C, T_{200} = 16°C]* and is found off the American coast to as far as the Tail of the Grand Bank where part of the warm current turns to flow northwards parallel to the eastern edge of the Grand Bank. At about latitude 50°N this changes direction to the northeast and leaves the ICNAF area. In the neighbourhood of the Mid-Atlantic Ridge, however, some of it a northward direction again and flows towards Iceland to form the Irminger Current. This current proceeds along the south and west coasts of Iceland and in the Denmark Section it bifurcates, one part passing southwards along the east coasts of Greenland, so that warm water re-enters the ICNAF area at Cape Farewell [T_0 = 3-8°C, T_{200} = 5°C] and flows northwards along the edge of the West Greenland banks.

Cold water with sub-zero temperatures is supplied from various sources. The East Greenland Current brings some from the North Polar Basin, over the East Greenland Shelf and between the coast and area and flows northwards over the West Greenland Banks. With the Irminger component, running outside it, the East Greenland component forms the West Greenland Current, which is therefore a current composed of two sharply contrasting water masses. Another source of cold water to the ICNAF area is the Baffin Land Current which flows south from Baffin Bay to eventually become the Labrador Current. This latter receives a contribution of warmer water from the West Greenland Current, which has a tendency to turn westwards, and cold water from Hudson Bay through Hudson

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*Note - The symbol T_z denotes the average annual temperature at depth z except in the case of T_0. In any region T_0 varies markedly both in space and time. It has therefore been given a range: the lower figure is the average February temperature in the coldest part of the region and the higher figure is the average August temperature in the warmest part.

Strait. Cold water originating from the Labrador Current rejoins it from the Gulf of St. Lawrence through Belle Isle Strait, after having flowed round Newfoundland. On reaching the Grand Banks the Labrador Current splits, part flowing along the outside slope of the bank and part flowing between the
& the shore. The former is therefore next to part of the Gulf Stream system, and cold water is
alongside warm. Large scale mixing occurs and a characteristic slope water is formed which is
along the edge of the shelf [T_{200} = 2–4°C, T_{400} = 3–8°C].

Within the Gulf of St. Lawrence [T_0 = −1–18°C, T_{200} = 3–5°C] there is an anti-clockwise circulation in the upper layers, with water entering from off the southwest Newfoundland coast and leaving past Cape Breton Island. Its most striking feature is the Gaspé Current on the southern side of the gulf: this contains the discharge of the St. Lawrence River. The water leaving Cabot Strait occupies most of the eastern part of the Scotian Shelf, but as it moves southwestwards it becomes confined to an inshore band. Between these coastal waters and the Gulf Stream is a well-defined band of slope water [T_{200} = 6–9°C]. A mixture of the inshore and offshore waters passes Cape Sable and enters the Gulf of Maine and Bay of Fundy to form part of the anti-clockwise circulation there [T_0 = 2–17°C, T_{200} = 6–8°C]. Water leaves the Gulf of Maine along the American coast past Cape Cod, giving a generally clockwise circulation around Georges Bank.

able part of the ICNAF area is subject to pack ice transported by the cold currents. The
heavy ice from the North Polar Basin: it moves up the West Greenland
coast and is maximal in April–June, at times reaching as far as Godthåb. The Baffin
brings ice from Baffin Bay southwards and in some years it extends across the Davis Strait to Greenland. This ice, together with that from Foxe Channel, is transported by the Labrador Current to the Grand Bank, which it reaches in January–March. Some of it enters the Gulf of St. Lawrence through Belle Isle Strait. Ice also leaves the Gulf past Cape Breton Island to move southwards towards Sable Island. Another part travels directly south and southwest from off southeastern Newfoundland. In addition to the pack ice there are icebergs. Some of these originate from East Greenland glaciers and travel northwards over the West Greenland Banks to as far as Holsteinborg. The West Greenland glaciers north of Holsteinborg are a major source of bergs and these travel in the Labrador Current to the Grand Bank.

Various oceanographic factors point to the ICNAF area being a region of high productivity. Strong winter cooling of the surface layers causes vertical mixing to great depths, 1,400 m in the case of the Labrador Sea. This ensures that the nutrient salt supply in the surface layers is replenished annually. In the spring and early summer ice melting causes a marked reduction in salinity, and hence density, in the surface layers. Stabilisation of the water column is thus provided and it allows phytoplankton production to start. Some upward movement of nutrient salts continues during spring and summer. The generally cyclonic circulation in the Labrador and Irminger Seas gives a divergent flow pattern in the surface layers leading to an upwards transport in the central parts of those seas. Again, off West Greenland, Labrador and Newfoundland where sharply contrasting water masses occur flowing side by side, either in the same direction or in opposite directions, pronounced turbulence occurs and in places, particularly along the continental slopes, this brings about an upward movement of nutrient-rich water

The ICNAF area has experienced marked long-term variations in climatic and oceanographic conditions. Most attention has been paid to air and sea temperature fluctuations. Sea surface temperatures off West Greenland showed a marked increase of about 1.8°C in the 1930s and they reached a maximum in the early 1930s, but fell by 0.8°C to a minimum in the early 1950s. Since then sea surface temperatures have been rising again. Also, a remarkable rise in temperatures at 200–300 m depth seems to have taken place between the early 1950s and the present time: it amounts to 2–3°C. In the coastal and shelf ar
off New England and the Maritime Provinces, a rise in sea surface temperature of 2.5°C seems to have taken place between the early 1920s and the early 1950s. It was most marked in the early 1950s, but during the last decade there has been a rapid downward trend in both surface temperatures and bottom
There is evidence that other changes in the oceanic circulation have accompanied these
ctuations. For example, the salinity of the Irminger component of the West Greenland
nt was at a high level between 1928 and 1948, but not again until after 1958.

PRIMARY PRODUCTION (based on a note by G.A. Riley)

The fingers of one hand are more than enough to count all the studies of phytoplankton productivity that have been carried out in this region with the use of modern methods, including chlorophyll analyses and experimental measurements of C^{14} uptake. Such a study is currently underway in St. Margaret's Bay, N.S., by the Marine Ecology Laboratory of the Bedford Institute, and there is another in Baie des Chaleurs, P.Q., by L. Legendre, a graduate student in the Dalhousie Institute of Oceanography. Neither has thus far been published (L.M. Dickie, personal communication, gives a first estimate of 125 gC/m²/year for St. Margaret's Bay).

A few measurements of chlorophyll and C^{14} uptake were obtained in oceanic waters of the Northwest Atlantic during the IGY. (CRAWFORD Cruise 16; DISCOVERY II Cruise 1, see Doty and Capurro 1961); however, in general coverage of this area was poor during the IGY, nor is the writer aware of any more extensive work subsequently. Krey (1967) has described some collections made in this area during the IGY, which consisted of weight determinations of total particulate matter and protein analyses. These may have some pertinence to the problem.

With regard to phytoplankton systematics and species distribution, a key reference is Brunel (1962). His monograph is particularly concerned with the phytoplankton of the Baie des Chaleurs, but it contains notes on ecology and more general distributions of species, and it provides an excellent list of references to the older literature.

Holmes (1965) has described the seasonal cycle of phytoplankton at a station in the Labrador Sea in terms of cell counts and species composition. Well to the south, similar work has been done in the Gulf of Maine (Bigelow, Lillick and Sears 1940, and the earlier papers by Bigelow) and Georges Bank (Sears 1941). Riley (1941) made estimates of phytoplankton productivity on Georges Bank by methods then in vogue but which have been superseded by better techniques.

In the long reach between the Labrador Sea and the Gulf of Maine we have only incidental information on species distribution. This area contains a remarkable variety of water masses - the Gulf of St. Lawrence, shelf and bank waters, slope water, Gulf Stream and Labrador Current. We have no detailed knowledge of seasonal cycles or the general level of productivity in any of these areas except the local inshore spots mentioned above. We can guess, on the basis of general knowledge of physical oceanography, that there may be some fairly large regional variations in productivity. It would be an intriguing venture to investigate some of these variations and their physical causes.

Because of this regional variation and the lack of extensive observations, it is not useful at present to attempt any estimate of the total primary production for the region as a whole, or for any individual sub-area.

4. SECONDARY PRODUCTION (Zooplankton and Benthos)

There are very few if any observations on the production of zooplankton or benthos. In the northern sub-areas the most extensive observations on the standing stock of zooplankton are those made during the NORWESTLANT surveys, principally of West Greenland. The reports of these surveys have now been published (ICNAF 1968). Other reports on zooplankton abundance have been published or submitted to ICNAF annual meetings, and there are some few observations on benthos, especially in the south. However, the observations are rather scattered, and in view of the probably large regional differences, no quantitative estimate of production is attempted.

5. FISH STOCKS AND FISHERIES

5.1 Statistics - Detailed statistics are published annually by ICNAF (Statistical Bulletin). These cover the years from 1951 for the ICNAF area proper, and include statistics for sub-area 6 from 1966 onwards. The data are broken down by species, area, month, and gear and include effort data. This is probably the best series of statistical data in any major sea area and is kept under regular review by ICNAF. The published statistics are of commercial catches only and exclude sports fishermen's catches. These are probably a significant proportion of the catches of several species (e.g. striped bass) in the southern part of the area. Present (1968) catches, by sub-area, and major species were (in '000 tons):

Table A1 - 1968 catches from the ICNAF sub-areas1/

	Greenland 1	Labrador 2	Newfoundland 3	Gulf and Nova Scotia 4	New England 5	Middle Atlantic4/ 6	Total
Cod	353	406	743	247	49	+	1,798
Haddock	+	+	6	46	44	+5/	96
Silver hake	-	-	-	3	80	235/	98
Redfish	9	5	48	103	7	-	172
Flounders	2	5	149	72	53	12	
Halibut	+	3	7	2	+	-	12
Herring	-	-	155	348	337	5	869
Other ground fish3/	7	4	29	35	58	30	
Other pelagic fish3/	-	-	1	22	51	174	
Other fish3/	1	4	17	19	50	45	
TOTAL2/	378	426	1,157	940	810	646	

Notes - + Denotes quantity less than 500 tons
1/ Excluding non-member countries of ICNAF. These took 141,000 tons in 1967, mainly cod
2/ Includes shellfish
3/ Definitions as used by ICNAF. "Other fish" includes some species which are mainly pelagic, e.g. salmon and capelin
4/ Figures for 1967; complete figures for 1968 not yet available
5/ 15,000 tons in 1968

A good systematic review of the fish species in the area, with some notes on their economic importance, is given by Leim and Scott (1966).

5.2 The fisheries - The main fisheries in the ICNAF area propse have been the demersal fisheries by trawls and line. In the southern sub-area (6), the two biggest fisheries have been for menhaden (mainly for reduction to meal and oil), and for oysters. The latter is discussed in detail in the mollusc chapter of this report. Three groups of species - cods, flatfishes, and redfish are mentioned in the ICNAF Convention as being of special interest to the Commission.

Cod (Gadus morhua) - This fishery is very old, and is carried out by large vessels from
Europe, including an increasing number of large freezing and factory trawlers and smaller vessels
America, using a range of gears, though with an increasing proportion of medium traw-
fisheries in sub-areas 3 and 4 have always been large, but that in sub-area 1 has
greatly in the last 10 years, whilst the trawl fishery in sub-area 2 has increased from
very little in 1959 to one of the most important (300,000 in 1965).

- Until 1965, haddock were fished in quantity only by
three countries; by US (and some Canadian) trawlers on Georges Bank (sub-area 5), and by Canada,
Spain and US (and USSR in 1960-1) in sub-areas 3 and 4; the catches in sub-area 3 depend greatly
on the strength of year-classes; recent year-classes have been very weak, and catches have been
low. In 1965, due in part to an outstanding year-class, there has been a large USSR fishery on

Redfish (Sebastes) - Redfish are caught almost exclusively by trawl. In the southern areas,
fishing by US and Canada has continued for many years; there have been fluctuations in the total
catch, and in its geographical distribution, but not on the scale of the redfish fisheries further
north. In the northern areas, fishing by European trawlers started in the late 1950s and has
greatly; on a succession of individual grounds, catches built up very rapidly, lasted
es years, and declined to a relatively low level. More recently catches seem to have
stable.

) - For a long time there has been a US trawl fishery in
40-50,000 tons. Since 1962 a large USSR fishery
has developed, first in sub-area 5 and later in sub-areas 4 and 6, reaching over 300,000 tons in
1965.

- These include several species. Much of the catch has been taken incidentally by for cod and haddock, but a number of US and Canadian vessels, using trawls and Danish seines, fish specially for flounders, and these catches have recently been increasing quite rapidly.

Herring (*Clupea harengus*) - The inshore fishery by Canada and US with a variety of gears has fluctuated around 130,000 tons for a long time. In 1960, an offshore trawl fishery by USSR developed in sub-area 5 reaching a peak catch of 160,000 tons in 1961. A Canadian purse-seine fishery has been increasing recently.

Other fish - A variety of other fish are caught, especially in sub-areas 4, 5 and 6. The more important of these are as follows: shark, sword fish and tuna, argentines and hakes (*Urophycis* spp.).

Molluscs and crustaceans - These will be dealt with in detail in separate reports dealing with the total world resources of these varieties. Important shellfish fisheries in the ICNAF area include the lobster, clams and scallops in sub-areas 4 and 5, and shrimps in sub-area 1.

5.3 Assessments - Regular assessments of the state of the important exploited stocks have been made by the Research and Statistics Committee of ICNAF, especially lately by its Assessments Sub-Committee (see ICNAF Annual Reports, especially supplement to Vol.11 and scientific reports in the annual ICNAF Redbooks).

Cod - All the stocks in the ICNAF region are heavily fished; good assessments have been made for most stocks, though in sub-area 2 the recent and rapid development of the fishery has made good assessment difficult until the last year or two. The detailed results are given in numerous ICNAF documents, summarised in various reports of the Assessments Sub-Committee. In no area can any substantial increase in sustained yield per recruit be expected from an increase in effort, but for few areas is the present fishing close to the maximum (if a maximum exists) in the yield per recruit curve. Some moderate increase in yield per recruit, perhaps of 10-20%, may, therefore, be achieved by proper management - use of larger meshes, moderate reduction in fishing, etc. - as appropriate for each stock.

Fluctuations in recruitment are important in some areas, e.g. West Greenland, but do not cause any great variation in the total catch from the whole area. The potential annual yield is thus slightly above the present annual catch - perhaps 1.5-1.75 million tons. However, it is possible that a small decrease in the water temperature at West Greenland could cause a substantial sustained decrease in year-class strength, or conversely, an increase in temperature increase the yield. At the worst, it appears that a sustained decrease in temperature at West Greenland of a few degrees could eliminate the cod stocks there, and would reduce the total cod yield from the ICNAF region by 300-400,000 tons. Such a climatic change would probably also adversely affect the Labrador cod stocks, and there are likely to be associated changes in other areas, both favourable and unfavourable.

Haddock - These stocks are also heavily fished and detailed assessments made especially of the Georges Bank (sub-area 5) stock (see several ICNAF documents and publications of US Bureau of Commercial Fisheries). A limited increase in yield per recruit could be achieved by suitable lations.

Year-class fluctuations are, however, very important in these fisheries; sub-area 3 have been reduced from 104,000 tons to 9,000 tons between 1955 and 1965 and sub-area 5 catches increased from 70,000 tons in 1964 to 155,000 tons in 1965, partly due to changes in year-class strength. The causes of these changes are not known. Precise estimates of the potential yield, therefore, cannot be used, but if future year-classes are not verv different from the average of those in the fishery between 1960 and 1964, then the potential yield would be a little above the the 1960-4 average (140,000 tons) i.e. 160-175,000 tons.

have been made of some of the redfish fisheries in the
1962, Rikhter 1965), the conclusions reached, especially on
the relation
yield, not been conclusive. Some of these uncertainties relate to the biology, especially the growth rate, an the interrelationships between different stocks. It appears that redfish are very slow growing (Kelleisen 1961), so that when fishing starts on a virgin stock the catches in the first year or so may represent the accumulated production of 10 years or more. Thus the first year's catch may be very much greater than the possible long-term annual catch. This is in agreement with the development of several redfish fisheries, especially in the northern areas, e.g. the successive annual redfish catches in

1957 have been (in '000 tons) 0, 77, 53, 83, 26, 8, 6, 27, 25. However, the peak may in some areas have been as much a reduction in effort, or a change in attention from redfish to cod, as to a real decrease in stocks. Thus in sub-area 5, Gulland (1961) noted that the relation between catch per unit effort and effort is not as clear as might be of the fishery (rapid rise to a peak, and then decline); nor has been a pronounced change in size composition. A reduction in average size following in Division 4 X (Beverton and Hodder 1962), though the resulting est of fishing and natural mortality suggested that the latter was the greater. Detailed analysis one area of the Gulf of Maine (F XXII), however, gave an estimate of fishing mortality about twice that of natural mortality. Similar analyses have not yet been done for the

The bigger uncertainty, however, concerns the identity of unit stocks, and especially the relation between the redfish exploited on the shelves, and the very large number of redfish larvae found over the deep oceans (e.g. Henderson 1965). Rough calculations suggest that the number of larvae found is about equal to the number that could be produced by the adult females present and exploited on the shelves; thus there would be no need to make hypotheses concerning separate if there was no mortality of larvae between extrusion and time of

Other species - Few detailed assessments have been made for other important fisheries some of which (e.g. silver hake and herring) have developed or increased very recently. Preliminary assessments of the silver hake in sub-area 5 (Gulland 1968) suggest that the fishing effort in 1965 reached a level beyond which no substantial increase in average catch could be expected, and that the greatest average catch from this sub-area would be 300-400,000 tons. Studies of the yellowtail flounder in sub-area 5 (Royce *et al.* 1959, Lux 1967) suggest that much of the fluctuations in this fishery are natural, especially due to year-class changes, and not to fishing. Simple correlation between effort and catch per unit effort may be misleading because effort declines when year-classes are poor (i.e. producing a positive rather than a negative correlation), though it appears fishing is now a major cause of mortality.

ESTIMATES OF POTENTIAL

Estimates of potential in the ICNAF area were discussed and presented at the 1968 ICNAF ing (ICNAF 1968b). These were based to some extent on an early draft of this section, and differ little from those pre

6.1 Sub-area 1 - West Greenland

Non-commercial catches - There are no data available of substantial catches of fish other than those already exploited. Commercial trawlers catch a few fish other than cod and redfish, mainly Greenland halibut and wolffish. A few American plaice are caught, but these are poor quality as food, being very watery. Some Macrurids have been caught in deep water (Meyer personal communication). Shrimp trawlers catch number of *Lycodes* spp. (Horsted personal communication).

Food of commercial species - Cod eat large quantities of capelin (*Mallotus villosus*) and sand-eel (*Ammodytes lancea*) (Hansen 1949) though it is not certain what proportion of the total food of cod are these fish; cod also eat euphausiids, squid, etc. Prawns also occur commonly in stomachs. Capelin is also eaten by whales and seals, to a total estimated by Sergeant (MS) as 0.23 million tons.

Eggs and larvae - Data from NORWESTLANT surveys are now available and give good information on the abundance of eggs and larvae in winter and spring.

General - There are not enough data for any good assessment, but the observations of Horsted and Smidt (1965) on capelin coming into the fjords suggest that an expansion of the present small scale industrial fishery for these species is possible. If 50% of the food of cod is capelin and sand-eel and the consumption of cod is five times the present annual catch, then cod eat not much less than 1 million tons of capelin and sand-eel. Most of the sand-eels occur on the offshore banks, whereas the capelin are not common, or at least most readily caught in the fjords. A small scale fishery for sand-eels began in 1967, with some promising catches of up to 30 tons in 4-5 hours.

6.2 Sub-area 2 - Labrador

Lightly fished stocks - Apart from cod and redfish, species caught in the area are wolffish (*Anarhichas* spp.) and flounders (mostly Greenland halibut, *Reinhardtius hippoglossoides*, and plaice Hippoglossoides platessoides). It is unlikely that the stock of wolffish is very large. Flounders occur quite regularly, and the trawls used are probably not the most efficient for flatfish, so that the potential might be quite large. In deep water, catches of Macrurids, Coryphaenoides rupestris have been reported by Dr. Meyer. A.May also reports that Macrourus berglax may be taken in quantity in 175-200 fm.

Food of commercial species - Cod have been reported feeding on capelin and lancet fish (Paralepis coregonoides) (Templeman 1965) as well as on invertebrates, including shrimp (Pandalus) (UK Research report for 1962). No quantitative data are available over deep water, salmon have been found feeding lancet fish (Notoscopelus spp.) and Paralepis coregonoides (Templeman 1965).

- Serebryakov (1965) reported catching eggs and larvae of myctophids, as well as s, redfish and American plaice, in sub-area 2, but without details of how many of the and larvae of the latter caught in the whole ICNAF area were in sub-area 2. Large quantities of larval squid (Gonatus spp.) were found in deep water east of Labrador by the GODTHAB expedition.

6.3 Sub-area 3 - Newfoundland

Lightly fished stocks - A general review of the Newfoundland resources has been given by Templeman (1966). Other than cod, haddock and redfish, demersal catches include substantial quantities of flounders, especially American plaice (Hippoglossoides platessoides). Assessments of these have not been completed, but studies now in hand and the recent increases in fishing will soon produce reasonable assessments. Length data showed that, at least until recently, only the biggest fish caught were landed; this suggests that the stock as a whole was only incompletely utilised. Squid are sometimes caught in quantities by trawl incidentally to other fish, as well as by jigging; the resource seems large. Ammodytes, and some capelin are reported by Nesstorff to be meshed in appreciable numbers over most of the Grand Bank in spring. Catches of herring in sub-area 3 have increased rapidly, 3,000 tons in 1964 to nearly 23,000 tons in 1966 - following the development of a fishery for reduction - and the stock may well be only lightly exploited. Saury (Scomberesox saurus) has occasionally been reported inshore in quantities, but the occurrence is very variable (Templeman and Fleming 1953). There may be substantial quantities offshore.

Food of commercial species - At, and soon after spawning, when the cod are inshore and feeding most intensively, 95% of their food is reported by Templeman to consist of capelin. Sand launce (Ammodytes) are an important food for cod on the offshore banks. Sperm whales have been recorded eating a variety of fish - capelin, cod, halibut, squid, wolffish, and a "small black fish" (Sergeant 1966). Capelin is a major item for whales and seals and their total consumption has been estimated at ca 0.5 million tons (Sergeant MS).

Lightly fished stocks - Besides the cod and haddock, which are presumed to be fairly fully exploited, and the redfish which may also, though with less confidence, be presumed to be fully exploited, demersal catches include quantities of flounders, and some hake (reported as red hake, but probably white hake, Musick 1967) in 4 T. Quantities of herring (44,000 tons in 1965) and mackerel are also caught. It has not yet been shown that these are fully exploited, and probably the catches of herring at least could be

6.5 Divisions 4 V, W, X - Nova Scotia

Other than cod and haddock (200,000 tons between them in 1965), the catches of demersal fish in 1965 included 50,000 tons of silver hake, and smaller quantities of flounders, redfish, pollock and red hake. Russian catches of argentines were 5,600 tons in 1965, but increased to 15,000 tons in 1966. Other species occasionally caught in quantity, but not generally landed, include skate and dogfish. The evidence on the state of the stocks of these species is not so clear as for cod and haddock, and probably the catches of some at least (e.g. argentines) could be increased by increased fishing. The history of the silver hake fishery, which increased from nearly nothing in 1961 to 123,000 tons in 1963, only to decline to a mere 10,000 tons in 1966, does not, however, suggest that this stock will provide a high sustained catch. The fishery is almost exclusively by USSR vessels, and the violent changes in catch reflect much more the changes in effort than changes in stock, though the most recent reduction in effort is probably due to a reduction in stock, which may itself have been caused by increased effort in the immediately preceding years. It is therefore in no way certain that the big catches in 1963-5 represented more than the stock could stand. Previous Canadian research trawl catches indicated large fluctuations in the silver hake stock in earlier years, which could not have been directly due to fishing.

Among pelagic fish, mackerel may be an important under-exploited resource both in this area and adjacent areas. Total catches by US and Canada have fluctuated widely – from up to 100,000 tons occasionally in the 19th century, to ca 30,000 tons in the 1930s (Sette and Needler 1934, Hoy and Clarke 1967), and 15,000 tons now. The cause of these changes is not know, but if they are due to changes in fishing, and not changes in the stock the opportunities for increasing the catches are obvious. Other under-exploited stocks probably include Ammodytes and possibly also myctophids.

6.6 Sub-area 5 – New England and Georges Bank

Unlike in other sub-areas, cod and haddock catches make up only a minor part of the total catch (ca 20% in 1966). The fisheries on some other species (redfish, yellowtail flounder) have continued long enough for reasonably good assessments to have been made, and these stocks seem to be fairly heavily exploited (Beverton and Hodder 1962, Lux 1967).

For some of the most important stocks (silver hake, and red and white hake, herring) no assessments have yet been completed by ICNAF. A preliminary assessment of the silver hake stocks has been made (Gulland 1968) which suggests that this species is about fully exploited. As pointed out by Musick (1967), there has been considerable confusion concerning the species breakdown in catches of Urophycis spp. USSR reports no catches of white hake (Urophycis tenuis), although some must be caught, if only incidentally to other species. It is probable that the bulk of the USSR catches, taken in winter on the southwest slopes of Georges Bank, were in fact red hake.

It is likely that the red hake has been heavily fished. Red hake is strongly concentrated in the winter, so that a large proportion of the stock might be taken with relatively low effort. Following the large USSR catches in 1965 and the beginning of 1966, the US catches in 1966 were very low (in the industrial fishery 12,900 tons in 1965 and 2,900 tons in 1966) (Graham 1967). However, since only two year-classes are present in the stock, and hence at most the accumulated production of two years, it is unlikely that the high total catches of 72,000 tons in 1965 and 87,000 tons in 1966 represent substantially more than the possible annual average catch, and may still be less than the potential catch. This, therefore, probably lies in the range 70–100,000 tons.

Data on herring are not yet so conclusive, but it appears that fishing is having an effect, and estimates, of stock size and fishing mortality from data on the quantity of spawn, though showing great variation from year to year, do suggest that fishing is a major source of mortality (Noskov and Zinkevich 1967).

., information on the abundance of fish available to bottom trawling is available from the results of the US research vessel surveys (Fritz 1965). This covers an area rather greater than sub-area 5 – from the Hudson Canyon to southern Nova Scotia. The distribution in terms of numbers caught per unit time is shown as contours for 20 species. The area of these contours and the catch rate within each contour can be used to give an index of abundance for each species for that part of the ICNAF area (5 and part of 4 X) included in the charts. These, together with the reported average length (in inches) and 1965 catches in sub-area 5 are given in Table A2.

No very precise analysis can be done with the figures in Table A2 since the species composition of the catch of a trawl always depends on how it is rigged. These surveys were carried out primarily for haddock, so haddock and similar species (e.g. cod, pollock) are probably better represented in the catches than others. Also only depths down to about 400 m were fished, so stocks in deeper water are under-estimates. Of the species in the table probably argentine and herring, at least, are under-represented because of depth or gear.

table is also of standing crop in numbers, while the major interest here is in potential production in weight. Despite that, there is a certain agreement between the figures of standing crop, and the actual total catches. Agreement is better within similar groups of fish, than between groups, e.g. the high total catch of yellowtail flounder suggest (as is very likely) that the gear used under-estimated the abundance of flatfishes relative to haddock and hakes – the presence or absence of tickler chains in front of the ground rope makes a big difference to catches of flatfish.

If this under-estimate applies to all flatfish, then it appears that the catches of
could be greatly increased, possibly by ten times. A comparison between the cod, haddoc
shows a relatively large catch of cod which is probably accounted for by the larger size of the individual fish, though also the 1965 cod catches were well above the previous average. Pollock catches are relatively low; the table suggests they might be increased to around the same level as cod.

Table A2 - Indices of abundance of certain species from trawl surveys and total international catch

Species	Length inches (cm)	Index	Catch (tons)
Sculpin	10 (25)	450	(c)
Goosefish (Angler)	24 (60)	70	205
Redfish	12 (30)	8,300	8,057
Scup	10 (25)	200	6,509
Butterfish	8 (20)	6,000	1,794
Witch flounder	18 (45)	60	2,162
Yellowtail flounder	14 (35)	400	37,397
Four-spot flounder	12 (30)	300	(c)
American dab (plaice)	24 (60)	1,000	3,523
Thorny skates	24 (60)	250	2,340(b)
Long-finned hake	10 (25)	750	(c)
Squirrel (Red) hake	12 (30)	2,700	72,068(a)
White hake	28 (70)	1,000	2,611(a)
Pollock	24 (60)	1,200	8,998
Haddock	18 (45)	8,500	154,725(d)
Cod	32 (80)	600	42,261
Silver hake	14 (35)	20,000	323,242
Argentine	12 (30)	600	9,453
Herring	10 (25)	2,000	74,303
Spiny dogfish	30 (75)	7,000	nil

Notes - (a) Red and white hake are probably not properly separated in the statistics; see text
(b) Includes all skates
(c) Not recorded separately in ICNAF statistics
(d) Average annual catches are much less

The comparison of the hakes is made difficult by the confusion of red and white hake (and perhaps also long-finned hake), in the published statistics (Musick 1967). Allowing for the difference in sizes of the individual fish, there is good agreement in Table A2 between red and silver hake, but the catches of white hake are very low. No white hake are reported in the USSR catches, and although their biggest catches of Urophycis spp. are taken from the winter concentrations on the edge of the banks, which are probably all red hake, it is certain that the USSR must catch some white hake. Allowing for this would give better agreement between all three hakes, though it would still appear that catches of white hake could be increased; since they are large fish, the potential catch should be rather larger than immediately suggested from the index of numbers, perhaps 25-30,000 tons. It appears, however, that white hake does not appear in the same concentrations as red hake, suitable for the operations of an industrial fishery or of factory ships. Catches of long-finned hake (Urophycis chesteri) could also be increased, but this is a small fish, and the potential is less, perhaps

The index of abundance in the table probably is an under-estimate for argentine and herring, so that although present catches fit well with the index of abundance, this is not evidence that a further increase in catches could not be attained. With sampling restricted to depths less than 200 m, the of argentines, which are generally found deeper, would be particularly under-estimated.

Of the other species in Table A2, redfish, butterfish and dogfish occur in the survey in sufficient numbers to suggest that their catches could be increased substantially. The occurrence of redfish in this list is surprising, since the history of this fishery in sub-area 5 - a rapid expansion in catches, reaching a peak of ca 60,000 tons in 1941, followed by a steady decline - suggests that it has been heavily fished. Part of the discrepancy may be explained by the slow growth and long life of redfish, so that the potential production is only a small fraction of the standing stock. Also, as pointed out by Gulland (1961) and by Beverton and Hodder (1962), there has not been such a marked decrease either in catch per unit effort or average size of fish as would be expected of a very heavily fished stock. Probably, therefore, redfish catches could be increased, though not to the extent suggested by the standing crop.

Sustained production of dogfish, too, because of their slow growth, and low fecundity, is likely to be a small fraction of the standing crop. Comparison with haddock and silver hake suggests a standing of the order of 100-200 tons, but the sustainable yield might be only 10% of this, 10-20,000 tons.

Dogfish are well known predators, and a reduction of the dogfish stocks might well lead to increased catches of other fish. This cannot be estimated at present nor indeed is it known whether reduction of other predators, including invertebrate predators of larval fish, might not have much greater effects.

Butterfish (*Poronotus triacanthus*) is a southern semi-pelagic species, mainly a summer and autumn migrant into ICNAF waters, at least inshore (Edwards 1966). Catches could certainly be increased, but they may be mostly outside the ICNAF area.

6.7 *Eggs and larvae (sub-areas 1-5)* - Serebryakov (1965) gave summaries of the catches of USSR surveys in March, April and May in sub-areas 2-5. The most numerous species were as follows:

Table A3 - Catches of eggs and larval fish in the ICNAF area, compared with the commercial catches

	Sub-areas in which caught	Eggs	Larvae	1965 catches ('000 tons) SUB-AREA				
				Total	2	3	4	5
Ammodytes spp.	3,4	-	12,500	-	-	-	-	-
Redfish	2,3,4,5	-	2,725	212	23	112	68	8
Cod	2,3,4,5	11,759	110	1,096	333	496	225	42
Myotophids	2,3,4,5	-	190	-	-	-	-	-
Capelin	3	-	162*	5	-	4	1	-
Chirolophis ascanii	4,5	-	57	-	-	-	-	-
Herring	5	-	52	262	-	8	180	74
American plaice	2,3,4,5	2,090	18	69	-	50	15	4
Neoliparis atlanticus	4	-	51	-	-	-	-	-
Yellowtail flounder (*Limanda ferruginea*)	3,4,5	1,250	3	45	-	3	5	37
Silver hake	3,4,5	467	20	373	-	-	50	323
Haddock	3,4,5	390	6	249	-	9	85	155
Witch (*Glyptocephalus cynoglossus*)	3,4	405	10	15	-	2	11	2
Cusk (*Brosme brosme*)	4,5	426	-	6	-	-	5	1
Pollock (saithe)	3	2	12	38	-	1	28	9
Urophycis spp.	4,5	11	5	92	-	2	15	75
Halibut	4	10	18	5	1	2	2	-

Note - * Capelin spawn in July/August so that the larvae are poorly represented in these samples

No other species occurred in quantity either in the plankton or in the commercial catches.

For those species which are known or believed to be rather fully exploited (cod, haddock, silver hake, some flounders) there is a degree of agreement between the numbers of eggs and/or larvae and the catches. Quantitatively for these species, the ratio of the catch in tons to the number of larvae varied between 4,000 (for American plaice) and 40,000 (for haddock). For no species were there large catches without there being also a substantial catch of larvae. Equally, abundant larvae correspond either to a major established fishery, or belong to species which are at present not commercially attractive. The exception is the halibut, which is heavily fished, but has relatively large numbers of larvae, though this may well be a sampling effect.

The table suggests very strongly that there are several species which can supply greatly increased catches, especially launce (*Ammodytes* spp.), myctophids (if they can be effectively harvested) and capelin. A comparison with other species suggests that the catches of launce might be of the order of millions of tons and of the other species of hundreds of thousands of tons. Redfish stocks may be particularly difficult to assess in this way. Redfish larvae are second only to *Ammodytes* in abundance; however, because there are no losses in the egg stage, the numbers of redfish larvae in the sea per unit weight of adult females may be considerably greater than for egg-producing species despite the generally lower fecundity. Cod eggs were much more abundant than redfish larvae (about in proportion to the catch) and in proportion to the respective parent stocks, the standing crop of redfish larvae may be more nearly equal to the standing crop of cod eggs than to the standing crop of cod larvae. More studies are needed on fecundity, survival, and duration of the various stages of both eggs and larvae. Also much more needs to be known about the relation of the redfish larvae - most of which are

Table A4 - Estimated potential, by sub-area (in '000 tons)

Species	1	2	3	4	5	Total	Actual catch 1967	Notes
Cod	350-450	300-400	450-600	250-300	20-30	1,400-1,800	1,685	
Haddock	-	-	10-70	50-60	50-70	100-200	117	Actual catch depends critically on year-classes
Pollock	-	-	(5)?	30-50	20-30	50-75	24	
Silver hake	-	-	+	50-150	300-400	350-500	127	(a)
White hake	-	-	(5)?	(10)?	25-30	40-60	10	
Red hake	-	-	-	(20)?	70-100	100-120	62	
Halibut	1	+	2	3	+	7-10	15	(b)
American plaice	(x10)?	(x10)?	(100+)?	(50+)?	(10)?	100-300	82	(c)
Greenland halibut	(20)?	(20)?	(20)?	+	-	50-100	27	? Good stocks in deep water
Yellowtail flounder	-	-	5?	10?	50?	50-100	38	
Witch	-	-	(10)?	(30)?	(10)?	20-50	21	
Other bottom fish	(x10)	(x10)	(x10)	(x10)	(x10)	(x100)	184	Other flounders, sharks, wolffish, etc.
Redfish	50?	50?	100+?	75+?	15-30	250+?	218	(d)
Butterfish	-	-	-	-	(50)?	(50)?	2	
Argentines	-	-	-	x10?	x10?	(x10)?	7	Historic catches up to 100,000 tons. Possibly a single stock
Mackerel	-	-	+	(50)?	(50)?	(100)?	34	
Capelin	(x100)?	(x100)?	(x100)?	-	-	(x100)	7	(e)
Herring	-	-	(x10)?	150-300?	150-300?	300-1,000	590	
Ammodytes	(x100)?	?	(x100)?	(x100)?	?	(x100)	-	Very big larval catches
Squid	-	-	(x100)?	(x100)?	?	(x100)	-	
Myctophids	?	?	?	?	?	(x100)	-	
Macrurids	(x10)?	(x10)?	(x10)?	?	?	(x10)	-	In deep water
Saury	-	-	?	?	?	-	-	(f)
TOTAL (A)	480	420	800	920	1,000			
TOTAL (B)	1,200	800	1,800	1,600	1,100	6,500		

Notes: (a) Silver hake potential in sub-area 4 estimated in comparison with sub-area 5. There are probably large variations in stock, with only very few fish present in some years (McCracken personal communication).

(b) Increased catches would require special protection of small fish. Large quantities are caught incidentally by other trawlers (Kohler 1967).

(c) Incidental catches of American plaice, and larval data, suggest a moderately large stock.

(d) There is a major uncertainty concerning the redfish on the continental shelves, and their relation to the large quantities of larvae caught over deep water. The short duration of some of the intense redfish fisheries suggests local potentials no greater than given here.

(e) Certainly a large stock. The feasibility of economic harvesting seems to depend on annual changes in distribution (Templeman 1948).

(f) The existence of a major oceanic stock of saury has been suggested (Ricker 1962), but there is no firm evidence.

caught over deep water (Henderson 1965) - to the stocks of redfish presently exploited on the continental shelf. Studies by Templeman (1967) on small numbers of redfish caught by long-lines over the deep water suggest on the basis of parasite infestation, that these oceanic redfish are indeed one or more stocks separate from the redfish on the shelves.

On the other hand, the table shows that in relation to the number of larvae, catches of hake (both silver hake, and other hakes - Urophycis spp.) are already high, though being summer spawners they are likely to be under-estimated by egg and larvae surveys in the spring. This suggests that these stocks may now be rather fully exploited.

6.8 Sub-area 6 - Middle Atlantic (US coast)

The biggest resource, other than the coastal resources of oysters, blue crabs, etc., which are not considered in detail here, is the menhaden. This appears to be heavily exploited, and no increase in yield seems likely.

The silver and red hakes were greatly reduced by the increased catches in 1965-6, and it seems doubtful if the high level of catch in 1966 could be maintained. However, under suitable management rather greater catches than the low 1967 catches should be achievable. Rough estimates are:

silver hake 50,000 tons	red hake 15,000 tons

There are few quantitative records of fish eggs and larvae. Off Virginia, in samples collected during all months of 1959, Massmann *et al.* (1961) found that 70% of all larvae collected were *Ammodytes americanus*. Flounders, butterfish (*Poronotus* spp.), sea robins (*Prionotus* spp.), anchovies (*Anchoa* spp.) and silverside (*Menidia menidia*) were the commonest other species, but none were particularly outstanding. This suggests that in this area, as in other parts of the North Atlantic, *Ammodytes* could provide large catches. Perhaps the resource potential could amount to the same as present catches in the North Sea, i.e. 100,000 tons annually. A conservative estimate of 10,000 tons has been made by Dr. K.A. Smith (personal communication).

No good estimate can be obtained for the other stocks. Probably the catches of demersal fish (other than hakes) can be increased - up to a total of around 150,000 tons. Catches of pelagic fish, other than menhaden, can also be increased; possibly the potential of anchovies, etc. is about the same, in total, as menhaden. Including sand-eels with pelagic fish gives a total potential of around 300,000 tons.

Squids used to be caught in pound nets along the Virginia, Delaware and Maryland coast, and some are caught as by-catch in trawling for other species. Adequate statistics are not available, but a moderately large potential seems not unlikely, say in the order of some tens of thousands of tons.

6.9 Marine mammals

Seals support important fisheries in the northern part of the area. The most important species commercially is the harp seal, though other species - hood seal, bearded seal, grey seal and harbour seal - are found. The state of the two principal stocks - the Gulf and Front herds - of harp seals has been well studied (see papers and reports of the 1967 ICNAF meeting, especially the report of the Sea Assessments Working Group). The Front herd in particular has been drastically reduced in recent years, the estimated production of pups having fallen from 473,000 in 1950 to 230,000 in 1966 (Sergeant 1966). The production of pups in the Gulf herd is around 250,000, and the sustainable yield around 85-90,000 pups, or rather less in terms of numbers of animals, if juveniles and adults are taken as well as pups. If the Front herd is rebuilt to its 1960 level a potential yield of perhaps as much as 250,000 pups could be taken.

At the optimum population attendance the number of adult harp seals could be around 1-1.5 million; the average weight of an adult is 350 lb (160 kg) or more (Templeman 1966), so that the population biomass, including immatures would be around 250,000 tons. The consumption of these animals must be large; capelin is known to be one important element in the diet (Sergeant MS). Further examination of the food might suggest possible resources unexploited by man, of fish or zooplankton.

Most species of large whales are found in the ICNAF area and have been intermittently hunted. Templeman (1966) suggests a sustainable yield of around 400 large baleen whales (blue, fin and sei). Pilot (or pothead) whales are taken in larger numbers (nearly 10,000 in 1956), but there are not sufficient data to estimate the potential yield.

6.10 Crustaceans and molluscs

These are, except for cephalopods, discussed separately in other sections of this paper. Squid are certainly common in the area. Catches of Illex illecebrosus up to some 10,000 tons are taken by Newfoundland, mainly for bait. The quantity taken varies from year to year, apparently due to changes in distribution. It is certain that the catches are only a small part of the potential. Most of the animals are only one year old (Squires 1957), so that the potential catch is likely to be a fairly high proportion of the probably large standing stock - maybe of the order of hundreds of thousands of tons.

7. SUMMARY AND DISCUSSION

7.1 Estimates of potential yield

Parts of the area are very highly productive and this is reflected in the importance of the area as a fishing ground to many nations. However, many of the stocks are now heavily exploited, and many of the lightly exploited stocks are less immediately attractive. The probable potential yields of the more important species may be as shown in Table A5.

In Table A4 a definite figure has been given whenever possible. For some stocks only an order of magnitude can be suggested. The figures for the total have been shown, (A) giving the sum of the potential yields for those stocks for which enough is known to give a definite estimate. Total (B) includes all stocks; the potential for those stocks for which only an order of magnitude can be suggested have been included by taking (x10)? as 30, (x100)? as 300, etc. The figures have been rounded off.

These estimates have been summarised in Table A5 and the potential yields expressed as yields per area of the shelf. These range from 36-121 kg/ha, which are very similar to the estimates in the Northeast Atlantic. The high value for West Greenland is probably due to much of the fish production coming from primary and secondary production occurring off the banks, and brought in by currents.

Table A5 - Summary of potential yields in the ICNAF sub-areas

	Statistical Area						
	1 West Greenland	2 Labrador	3 Newfoundland	4 Nova Scotia	5 New England	6 Middle Atlantic	TOTAL
Area ('000 km²)	85	100	490	310	185	90	
Potential catches ('000 tons)							
Pelagic	600	300	900	900	400	300	3,400
Demersal	600	500	900	700	700	150	3,550
TOTAL	1,200	800	1,800	1,600	1,100	450	6,950
Potential (kg/ha)							
Pelagic	71	30	18	29	21	33	
Demersal	71	50	18	23	39	17	
TOTAL	140	80	36	52	60	50	
1967 catches ('000 tons)							
Pelagic	5	1	92	286	297	180(a)	861
Demersal	454	327	1,011	410	341	80(a)	2,623
Molluscs(b)	-	-	-	10	78	354	442
Crustaceans	6	-	-	17	15	44	82
TOTAL	465	328	1,103	723	732	658	4,009

Notes - (a) Recorded figures (Appendix Table A2) rounded up slightly to allow for unreported catch by sports fishermen

(b) Squids included with pelagic fish

7.2 Requirements for future research

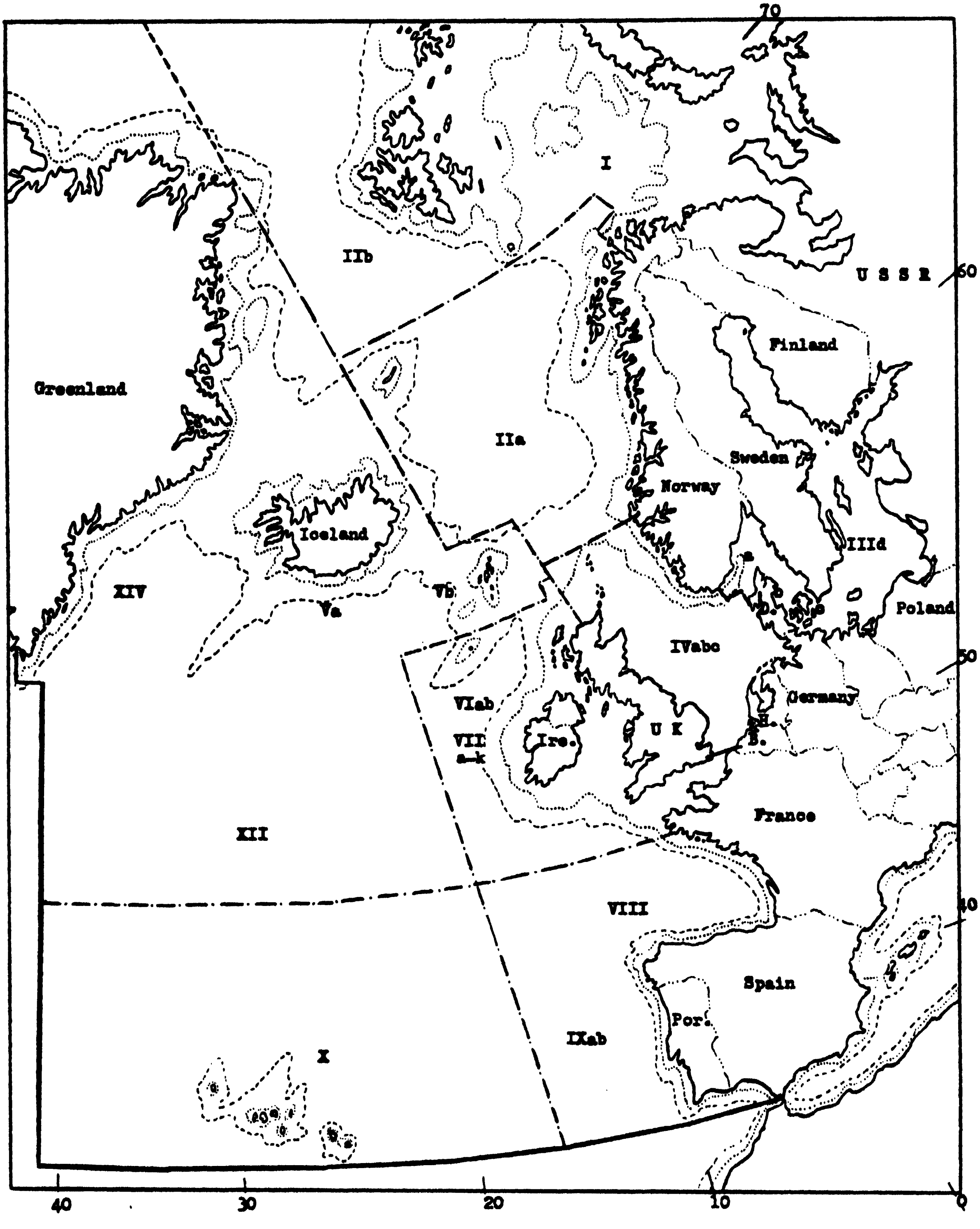
The ICNAF area is one of the best known in the world, and for the main purposes of the present study (rough assessment of the state of the stocks, and identification of opportunities for increased catches), many of the estimates are adequate. For the most heavily fished stocks (cod and haddock) the main uncertainty concerns the relation between adult stock and subsequent recruitment (e.g. is the low recruitment to the Georges Bank haddock since the 1963 year-class due to low adult stock?). This relation is critical in determining the effect of high levels of fishing mortality, and the optimum level of fishing, but does not much affect the estimate of potential yield.

The estimate of redfish potential still has a great uncertainty because of the unknown degree of connection between the exploited shelf fish and the oceanic fish. Tagging would resolve this, but appears impracticable. Another possibility is an examination of the apparent abundance of oceanic larvae, e.g. in plankton recorder catches, to determine whether there has been any decrease associated with the decrease in the shelf stocks.

For other exploited stocks (herring, flounders, hakes, etc.) continued studies along established lines (analysis of catch and effort statistics, age composition data, etc.) may be expected to give improved estimates shortly, especially in view of the large changes in fishing effort on these stocks that have recently occurred. The estimates for other resources (*Ammodytes*, squid, etc.), while very imprecise, are less easy to improve. Ultimately, the most reliable estimates will be obtained after substantial exploitation occurs. Surveys - of eggs and larvae, or with fishing gear or acoustically - can give improved estimates of standing stock, though for some species, e.g. squid, the first requirement is to devise suitable methods for sampling the animals.

These totals should not be considered as simply additive; sufficiently large catches of capelin, for example, will tend to decrease the food supply to, and hence ultimately the catches from, the cod stock. Equally the cod fishery must have, to some extent, reduced the production on capelin, and hence increased the potential catches by man of capelin, and other species. However, there is no evidence to suggest the cod catches would be adversely affected to any measurable degree by even quite a substantial capelin fishery. Table A4 does, however, suggest that while the catches of the traditional species may not be greatly increased, the total catch from the ICNAF area might well be doubled in weight by fishing for other species though at present these species are less valuable than those now being heavily exploited. Apart from the myctophids, which would present some technical problems of both catching and processing, the most promising species, or closely related species (capelin, *Ammodytes*, and squid), are the objectives of major fisheries in other areas. For many of these a closer examination of the data presently available on distribution and likely density and a comparison with other areas should provide better estimates than the rough figures above.

B - NORTHEAST ATLANTIC



B - NORTHEAST ATLANTIC

Depth contours at 200 and 2,000

1. TOPOGRAPHY

1.1 The area treated here is the same as the ICES statistical area; that is, from Cape Farewell at the northwest and Novaya Zemlya at the northeast to the latitude of Gibraltar (36°N) in the south. For subsequent analysis it is convenient to consider five major subdivisions: northern waters (sub-areas I, II, V and XIV of ICES); the North Sea plus the Skagerrak and Kattegat (sub-area IV and Division III a); south and west of the British Isles (VI and VII); the Baltic, plus the Belts (Divisions III b, c and d) and southern waters between 36°N and 48°N (VIII and IX).

This breakdown agrees very closely with that of the North East Atlantic Fisheries Commission; the first and last areas correspond to NEAFC Regions I and III respectively, and the second and third of the present areas correspond to Region II of NEAFC. The Baltic lies outside the NEAFC

1.2 The continental shelf in the northern area consists of (i) the long eastern coast of Greenland; most of this is ice-covered and the productive area is relatively quite small; (ii) the area round Iceland; this is variable in extent, reaching up to around 50 mi from the coast, with the particular large areas of Faxa Bay and Breda Bay on the west coast (the total area out to the 100 fm contour is around 125,000 km^2); (iii) the area round Faroes, including the Faroe Bank, which is separated from the shallow waters round the islands by a channel deep enough to form a barrier to the movement of demersal fish (the total area is about 17,000 km^2); (iv) the west and north coasts of Norway (from 62°N) (this is a narrow and generally rocky shelf). Trawling is possible in a few areas, the most important being the very narrow grounds in the north off Lofoten; (v) the Barents Sea - this is a very large area ca 1,300,000 km^2, bounded by Spitsbergen, Frans Joseph Land and Novaya Zemlya, of which the north-eastern part is generally ice-covered for much of the year, and has limited production. For fishery purposes the important parts are the south-eastern part of the Barents Sea (part of the sub-area I of ICES and the Bear Island-Spitsbergen Shelf (Division II b), which is separated from the south-eastern part by a moderately deep Bear Island Channel (ca 600 m).

As considered here, and as defined for purposes of fishery statistics, the North Sea and adjacent waters are bounded in the south at 51°N, in the northwest at 4°W and 62°W (i.e. lines running a little west and north of the Orkneys and Shetlands), and lines at the southern end of the Kattegat joining Zealand to the coasts of Jutland and Sweden. The approximate area of shelf less than 200 m (which includes all this area except a small part in the northwest, and a deep channel off the Norwegian coast) is about 550,000 km^2 in the North Sea proper (Fairbridge, 1966, gives an area of 575,000 km^2 for an area which includes the Norwegian deep water, but excludes the area to the west of the Orkneys). South of the Dogger Bank the water is shallow (less than 80 m), but gradually deepens northwards from the Dogger Bank to 100 fm and more. The Skagerrak and Kattegat contain a further area of about 40,000 km^2.

The other waters round the British Isles can be divided into (i) the isolated Rockall Bank (ICES Region VI b, area within 200 m about 12,000 km^2); (ii) the west coasts of Scotland and Ireland to 54°30'N (VI a, about 100,000 km^2), which includes both the area of generally rocky and uneven bottom, between the Hebrides and Scottish mainland, and the fairly wide (about 90 km) and rather smoother shelf between the Hebrides and the edge of the continental shelf; (iii) the shallow (ca 50 m) Irish Sea (Division VII a, about 100,000 km^2); (iv) the west coast of Ireland, including the partially isolated Porcupine Bank - between 54°N and 52°30'N (Divisions VII b and c). The shelf deepens rapidly to 100 m, but is fairly wide between 100 and 200 m; total area to 200 m is around 30,000 km^2; (v) the British Channel (Division VII f, about 12,000 km^2); (vi) the English Channel (Divisions VII d and e), which has an area of about 75,000 km^2, and an average depth of some 50 m; (vii) the area south-west of Ireland (Divisions VII g, h, j, k), where there is a wide shelf, mostly between 100 and 200 m; the total area is about 170,000 km^2.

The total area of the Baltic is about 420,000 km^2. All of it is shallow (average ca 50 m), and the Gulfs of Bothnia and Finland, and other areas are ice-covered for much of the winter. Much of Skagerrak is moderately deep (7,500 m).

The southern waters area, south of 48°N, can be split into the part off the French coast, on the east side of the Bay of Biscay, where the continental shelf is moderately wide - about 100 n.mi giving a total area of shelf out to 200 m of 100 km^2, and the very much narrower shelf along the Spanish and Portuguese coasts about 40 km wide, and an area of 60,000 km^2.

2. HYDROGRAPHY

The hydrography of the area is dominated by the North Atlantic Current and its offshoots, which bring warm water over most of the northern parts of the area (Schott 1942). The warm Irminger Current flowing anti-clockwise along the south of Iceland is separated from the Greenland coast by the cold East Greenland Current. The north and east coasts of Iceland are also covered by predominantly cold water from the East Iceland Current.

The longest extension of the North Atlantic Current after passing the Faroes goes northward along the west coast of Norway, and divides into two arms, one northwards to the west coast of Spitsbergen and the other along the north coast of Norway. These two currents cover much of the western and southern parts of the Barents Sea with relatively warm (ca 4°C) and productive water.

Atlantic water flowing round the north of the Shetlands forms the main current into the North Sea, with a smaller inflow between Shetland and Scotland and also from the English Channel. These, with the generally strong tidal movements produce a complex, but generally anti-clockwise circulation within the North Sea. South of the Dogger, the water column is mixed for the whole year, but in the north a thermocline forms in the summer.

With its narrow and shallow entrance the Baltic is cut off from major oceanic influences. Inflow of freshwater is very large (about 2% of the total volume) so that the salinity is low, varying from 25-30°/oo on the bottom in the Belts, to 5°/oo or less on the surface in the Gulf of Bothnia and the Gulf of Finland. Outflow of low salinity water on the surface is balanced by inflow of higher salinity on the bottom. Some major changes in the total productivity of the Baltic may be linked with changes in the inflow of water from the North Sea.

3. PRIMARY PRODUCTION

Studies of primary production have been made by a large number of authors using a variety of methods in different parts of the area. A detailed review will not be attempted here, especially as many of the studies have been made in inshore coastal and estuarine waters where there are likely to be large real differences in annual primary production, and individual observations may be far from typical of the whole area. A chart of primary production throughout the world (Hela and Laevastu 1962) suggests that the Northeast Atlantic especially in the area between Faroes and Iceland contains some of the most productive areas of the world. Variations of productivity within the area might be best studied by examination of plankton standing crop (e.g. from plankton recorder data), rather than by extensive direct measurement of production.

In the North Sea, Steele (1965) considered that the annual production was in the range 50-150 gC/m^2/year and used a figure of 100 gC/m^2/year. Cushing (personal communication) considers the possible range is as wide as 44-200 gC/m^2/year. For the present purpose, a figure of 100 gC/m^2/year will be used. This gives a total fixation of carbon of 55 x 10^6 tons per year. (550 x 10^6 tons wet weight, if carbon is 10% of wet weight.)

Russian estimates (Bogdanov, personal communication) for Barents Sea is of an annual production of 1,200 x 10^6 tons wet weight of phytoplankton (approximately 1,000 g/m^2/year).

4. SECONDARY PRODUCTION

4.1 Zooplankton

The regular plankton recorder surveys carried out by Edinburgh Oceanographic Laboratory give very good information on the distribution and abundance in the area covered - the North Sea and the Atlantic from Iceland and west Norway in the north to Ushant in the south. These surveys give the distribution in terms of number per unit volume just below the surface and, therefore, cannot be used to give quantitative estimates of the abundance per unit area unless assumptions are made concerning the vertical distribution of the organisms concerned. However, they do provide much the best presently available data on the distribution of plankton in the area.

The distribution of copepods, probably the most important element in the zooplankton, is given by Colebrook *et al.* (1961). The most important elements are *Acartia* spp. (up to 1,000 + individuals per sample - 3 m^3); *Calanus finmarchicus* (300 + per sample) and *Para-* and *Pseudocalanus* spp. (1,000 + per sample). To estimate total standing crop in weight there should be an adjustment for the different size; *Para-* and *Pseudocalanus* are about one third the length (and, therefore, about one thirtieth the weight) of *Calanus* (Cushing and Vucetic 1963), and *Acartia* is also smaller than *Calanus*.

Allowing for these differences in size the largest average standing crops are in the oceanic areas off the west coast of Norway and parts of the area between Iceland and Faroes, with more than 300 Calanus per sample. If it is assumed that the average weight of the individual is that of a stage IV, and using the length of 2.3 mm, and quoted length-weight relation of Kamshilov (1951) given (for the North Sea) by Cushing and Vucetic, the average wet weight is around 0.25 mg. The total weight in the area of greatest standing crop is then $\geq$ 75 mg/sample, or > 25 mg/m^3, or (if the surface density applies to a depth of 100 m), > 2.5 g/m^2.

Slightly lower standing crop (100-300 Calanus/sample or perhaps 0.8-2.5 g/m^2) were found in the northern North Sea, other parts of the area southeast of Iceland, west of Scotland, and (allowing for a proportionally greater contribution of other copepods) south of Ireland.

In other parts of the area studied (southern North Sea, and west of Ushant), the standing crop, particularly of Calanus was low - even allowing for the larger number of other species, probably not more than equivalent to 50 Calanus per sample, or 0.4 g/m^2 wet weight.

These are standing crops. There are several generations each year, so that the production will be several times the standing crop. For instance the data of the number of Calanus caught during the later cruises reported by Cushing and Vucetic, during which recruitment of stage I Calanus was small, gives an instantaneous mortality rate of 0.3 per 10 days or 11.0 per year. If this was the average mortality rate throughout the year then the production would be 11 times the standing crop. Taking 10 as a convenient approximate figure - which may not be constant over the whole area considered - estimates of annual copepod production of from 4 to over 25 g/m^2 wet weight are obtained.

More detailed studies of zooplankton standing crop (though usually not of production) have been made for particular areas, especially in the North Sea and English Channel. (These have not yet been examined in detail). Steele (1965), using results of the Aberdeen Laboratory, derives estimates of Calanus production in the northern North Sea of a minimum of 6.4 gC/m^2 per year. This is equivalent of ca 65 g/m^2 wet weight - considerably greater than that obtained above. Apart from possible real differences due to place or time of sampling the discrepancies may be because the plankton recorder under-estimates the true abundance, or incorrect values of mean weight of individuals used here.

For other parts of the Northeast Atlantic Russian sources (Bogdanov personal communication) give for the Barents Sea a total zooplankton biomass of 40-42 x 10^6 tons and (assuming 2-3 generations per year) an annual production of 100 x 10^6 tons wet weight. For the area of 1,400,000 km^2, these figures are equivalent to an average standing crop of ca 30 g/m^2 and production of 70 g/m^2 wet weight. The conversion factor from standing crop to production may be too low. For example, if there are 2 generations per year the standing crop is likely to be considerably less than the production of one generation unless there is considerable overlap between generations and there is little mortality among one generation until the next generation is well grown. Against this, some of the important elements in the Barents Sea zooplankton may have only one generation per year.

4.2 Benthos

Though quantitative work on benthos has a long history in the area (Petersen 1918, Belgrad 1930), there have been comparatively few recent studies, particularly on production. As pointed out by Steele (1965) estimation of production is made more difficult by the wide range in the ratio of standing crop: production for different elements in the bottom fauna. Steele derives an estimate for annual production in the North Sea of 5 gC/m^2 or perhaps 50 g/m^2 wet weight (ignoring shells of molluscs, etc.).

In the Baltic estimates of benthos standing crop have been made for the whole area (Zenkevitch 1963) as follows:

Table B1 - Standing stock of benthos in the Baltic

Area	Total biomass (thousand tons)	Density (g/m²
North of Gulf of Bothnia	9	0.2
South of Gulf of Bothnia	1,200	12.4
Gulf of Finland	1,200	57.0
Gotland Basin	3,500	25.0
Southern Baltic	4,600	60.0
TOTAL	10,509	Average 31.5

Assuming that the mean duration of life of the benthos is one year these figures might be taken as equal to the annual production. (Further data on benthos production are available in the literature, and should be examined.)

5. FISH[1]

5.1 The fisheries

The fisheries of the area include some of the oldest in the world. The North Sea was the cradle of modern trawling, and intense trawling has been carried on in all parts of the area for a considerable period. The area most recently exploited has been the East Greenland area, first by German trawlers in 1950, and later by some other countries. Successively in different parts of the region the trend has been first an increase in fishing, followed by a stabilisation as catch rates drop and the increased effort is diverted to more distant waters.

While trawling is the most important gear for demersal species other important fisheries for cod and other fish are carried on by other gears, especially in northern Norway (particularly Lofoten), and Iceland. Here purse seines have been recently introduced, in addition to, and partly in replacement of, other gears, hand and longlines and gill nets. Especially in the North Sea Danish seining, both by the Danish (anchor) and Scottish (fly-dragging) methods are important for plaice, cod, haddock and whiting. In southern waters bull (pair) trawls are used.

Herring fisheries off Iceland, Norway and in the North Sea, are among the most important and longest established, but recent developments have changed the nature of the fisheries. In the North Sea, the traditional drift net was slowly replaced by trawl fishing (both bottom trawls, and particularly most recently, pelagic trawls) until, in 1964, the Norwegians developed purse-seining in the open northern North Sea. The major part of the catch is now taken by purse-seine. Also the northern stocks, off Iceland and Norway, and in the high seas between, are now mainly exploited by purse seine, but there is an important USSR fishery with drift net in the open Atlantic.

In the southern areas there have been fewer changes in the pelagic fisheries; the most important remains that for young pilchard (sardine).

An important development within the last ten years has been the growth of fisheries specifically for fish meal. Apart from the growth of fisheries on species already exploited (herring, sprats, mackerel), new fisheries have started, especially in the North Sea, for species previously unfished - Ammodytes, Trisopterus esmarkii, etc. These are largely caught by small-meshed trawls, and which has caused some difficulties in management through the incidental catches of other species - haddock, whiting, etc.

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[1] Crustaceans, and molluscs (other than cephalopods) are being examined in a separate review and are not considered here.

5.2 Statistics

Statistics of catches in the area (including some adjacent waters - West Greenland, Northwest Africa) and some data on fishing effort have been collected and published by ICES since 1906. The general statistics are given in the annual Bulletin Statistique, while in the last few years detailed statistics of catches and effort by small areas, and also length compositions, have been issued in the Statistical Newsletter for certain stocks. These statistics are outstanding both in detail and in the length of time covered. Until 1964 catches of non-member countries of ICES were not included; the most important are the catches of East Germany especially in the Baltic. For some countries the reported area of capture corresponds to the area in which the port of landing is situated, and not where fishing was actually carried out. This has lead, for example, to a serious under-estimation of Spanish fishing off the west coast of the British Isles. The summary statistics for the year 1962-66 are given in Appendix Table B1.

5.3 Stock assessment

Detailed studies have been carried out for some stocks - the demersal stocks of the northern area, and the herring - by working groups set up by ICES to advise the North East Atlantic Fisheries Commission (NEAFC). For the demersal stocks the conclusions have been quite clear, but considerable doubt still remains concerning the precise status of the herring stocks. Another ICES group is now considering the North Sea stocks; assessments have been made also by individual scientists. Little work has, however, been published concerning the southern stocks, or those to the west of the British Isles. The present state of knowledge of the stocks in the various areas is given below.

5.4 Northern area (Greenland to Barents Sea)

(a) Separation of stocks

Deep water maintains the separation of the major demersal stocks (cod, haddock, plaice and possibly coalfish) - those at Iceland (but there is significant movement of cod between Iceland and East and West Greenland), the northeast Arctic (Barents Sea, Bear Island-Spitsbergen, and northwest Norway), and Faroes (where the stocks on Faroe Bank are largely separate from those round the Islands). There is some interchange of coalfish between these areas, and with the stocks round the north of Scotland (ICES 1965). The separation of redfish stocks is not known, particularly regarding the relation of the stocks now exploited on the continental shelves with the large number of larvae found over deep water (Henderson 1965), though it is probable that the stocks in the northwest are separate from the others.

There are separate groups of herring with both spring and summer spawning. Spring spawning in the area occurs off the west coast of Norway, south Iceland, and on the Faroe Plateau. Summer spawning occurs mainly along the south and west coasts of Iceland. Though separate at spawning time they mix on the feeding grounds north and east of Iceland. Herring from the Atlanto-Scandian stock of herring also spawn on the northeastern and northern edges of the North Sea Shelf, and off the north and west of Scotland (ICES, 1966 a, Annex II). When caught on these grounds they will appear in the total catch statistics for the North Sea or west of Scotland, but they are quite distinct from the North Sea stocks. With these exceptions there is probably little movement into or out of the area.

(b) Demersal stocks in the northeast

Cod and haddock

The state of the cod and haddock stocks in the northeast has been reviewed by the ICES Arctic Working Group (ICES, 1966 a, Annex I). This showed that both stocks had been greatly affected by fishing, and that increased average catches could be achieved only by reducing the amount of fishing, or by protection of the small fish (e.g. use of larger effective mesh size by trawlers). The actual average catch will depend on the recruitment; for cod this appears to be related to the parent stock, with maximum recruitment possibly occurring at an intermediate parent stock (Garrod 1966). Between 1945 and 1963 the average cod catch was 800,000 tons. These catches include an element from the reduction in standing crop as well as from current production, but allowing for better management, the possible annual catch from year-classes with the same average strength as those in the fishery between 1945 and 1963 (i.e. those from about 1937 to 1958) is in the range 800,000 - 1 million tons. If, however, the stock/recruitment curve has the dome shape suggested by Garrod, then if the adult stock is maintained at the level giving the greatest average year-class, the year-class strength might be 25% above the 1937-58 average. Thus, unless there are other density-dependent effects, e.g. reduced growth such as suggested by Ponomarenko (1967) would give possible average catches of 1 to 1.25 million tons. Also, if adequate management measures are not introduced, and the adult stock remains at this present low level, then average recruitment may also remain very low, and average catches be perhaps no more than 300-500,000 tons.

Less is known concerning the state of the haddock stocks; but the available evidence suggests that with proper management average catches could be rather higher than the recent average, say, a potential 200,000 tons.

Coalfish

The state of the saithe (coalfish) stocks has been examined by the ICES coalfish working group (ICES 1965). This could not reach any very precise estimates of the effect of fishing. Unlike the cod and haddock, whose main area of feeding and growth is the Barents Sea, it appears that the main area for juvenile coalfish is along the western Norwegian coast, where they are fished by purse seines. Catches fluctuate considerably, largely due to real changes in abundance (year-class strength) (Olsen 1966). These fluctuations tend to mask any relation between catch per unit effort and effort. Estimates of total mortality coefficient average around 0.5-0.6; estimates of fishing mortality from tagging are 0.2-0.3 (ICES) though the age composition of Polish catches in 1967 (Draganik 1967) suggested a higher total motality of 0.99. This suggests that moderate increase in fishing, from the level of the early 1960s, would give increased yield. An examination of Beverton and Holt's (1964) yield tables for $E = \frac{F}{(F + M)} = 0.4-0.5$ suggests that the fishing effort might be as much as double, though this probably would only increase the catch by perhaps 30-50%. The average landings from 1954-63 were 14,000 tons in Region I, 106,000 tons in Region II, 800 tons in Region IIb. A rough estimate of the potential average catch is, therefore, 120,000 x 1.4 = 175,000 tons. The fact that increased abundance is correlated with reduced growth (Olsen 1966) suggests that food is a limiting factor.

Redfish

Less is known of the redfish stocks. Catches since 1951 have fluctuated between 109,000 tons (in 1959) and 26,000 tons (in 1962), with an average of 62,000. The decline from the 1959 peak suggests that fishing has seriously reduced the stocks, though the magnitude of the decline may be due more to reduced effort than reduced catch per unit effort. The supposition that the stocks are fairly heavily fished is supported by the analysis of Sorokin (1964) based on changes in the sex ratio. Potential average annual catches may be in the region of 50-100,000 tons.

Other exploited demersal species

The only other demersal species, the subject of a specific fishery, is the Greenland halibut, fished in deep water. This probably accounts for the major part of the catches of various Pleuronectiformes reported landed by Norway from Region IIa which have increased from 10,000 tons in 1962 to 17,500 tons in 1965. The substantial catches of 'halibut' reported by USSR in the Bulletin Statistique - 5,000 tons in Region IIb, and 11,000 tons in Region IIa in 1965 - are probably not true halibut, but also Greenland halibut. There are no good data for stock assessment though in view of the probably long life of the fish it is doubtful if the average potential yield is very high. Possibly the large Norwegian catches are from an accumulated stock and cannot be maintained. A figure of 20,000 to 40,000 tons might be guessed. A somewhat less specialised fishery is that for plaice in the Barents Sea, especially off the North Russian coast, off Cape Kanin. This was the first stock exploited in the area (Atkinson 1908), and specialist English skippers make occasional trips specifically for plaice. The stock is probably heavily exploited (Gulland 1964) and the potential yield, with proper management, is rather above the recent average. This is difficult to establish exactly because in the USSR statistics plaice are combined with other flatfish, and sometimes recorded in the Bulletin Statistique as 'plaice' and sometimes as 'other Pleuronectiformes'. This potential is probably at most 5-10,000 tons.

Halibut catches, assuming the reported USSR catches are mainly Greenland halibut, are small, ca 4,000 tons. No appreciable increase seems possible.

A variety of other demersal species, ling, tusk, catfish (wolffish), etc., are landed, mainly caught incidentally to the cod fisheries, to a total of ca 50,000 tons. These are all large and long-lived and are probably quite heavily fished. It is unlikely that any great increase can be achieved.

(c) Demersal stocks in the northwest (Faroes to East Greenland)

The state of the major stocks at present exploited has been reviewed by the ICES north-western working group (ICES 1966). This group which was chiefly concerned with the probable effects of increase in trawl mesh size concluded that these stocks are generally heavily fished, in agreement with other published studies by individual scientists, e.g. Russel (1942), Parrish and Jones (1953), Jonsson (1960), Gulland (1961), Jones (1966) and by the previous ICES group (ICES 1962).

Cod and haddock at Iceland were considered to be so heavily fished that further increase in fishing would not increase the long-term average catch, though such a small increase might result from a moderate decrease in effort. Small increases would be achieved by better protection of young fish, e.g. by using a larger mesh size. This might raise the average annual catch to around 500,000 tons of cod, and perhaps 75-100,000 tons of haddock, depending on the strength of year-classes. There is some evidence that a reduced adult stock of Icelandic cod results in smaller year-classes (Jonsson 1966); if so, proper management might result in rather greater yields than above, and more particularly without management there is likely to be a further decline in catches.

Cod and haddock at Faroes (including both the Faroes Banks and Plateau stocks) are also heavily fished, but changes in fishing effort were not explicitly considered by the ICES group. Jones (1966) concluded that a moderate decrease in effort would give a slight increase in yield of cod, and the same is probably true of haddock. Average catches slightly above the recent average should be possible say 35,000 tons of cod, and 25,000 tons of haddock, though actual catches in any year, particularly of haddock, will depend greatly on the strength of the year-classes.

The cod stocks at East Greenland are less heavily fished, but the total stock is probably small and potential catches are unlikely to be much greater than recent catches, possibly as much as 25,000 tons.

The state of the coalfish stocks is, as noted for the north-eastern area, less well-known (ICES 1965). They are probably less heavily exploited than cod or haddock, but tagging experiments off North Iceland, which gave 30% recaptures in the local purse-seine fishery within 12 months (Jonsson and Jones 1965) suggest at least a locally high fishing rate. Probably increased fishing, especially on the larger fish - the fish caught for tagging in the purse-seine fishery were nearly all between 40 and 62 cm (1964), or 40 and 68 cm (1965), while the offshore English and German trawl catches, at least in 1955-59 ranged up to 120 cm, with modes around 70-80 cm (ICES 1965, Fig. 9) - would give some increase in average catches, possibly as much as 50-100% above the recent level, i.e. perhaps up to 100,000 tons at Iceland, and 20,000 tons from Faroes.

The ICES group considered that fishing had caused a real decline in redfish stocks at Iceland and East Greenland. Total catches from Iceland declined from a peak of 170,000 tons in 1951 to 70,000 tons in 1961, though they have recovered to 114,000 tons in 1965. Some of these changes are directly due to changes in effort (Icelandic fishing for redfish has decreased greatly, while the attention of German trawlers has to some extent been diverted from redfish to cod), so it is by no means certain that 170,000 tons is more than can be maintained as a long-term average annual catch though for a long-lived fish, such as the redfish, the annual yields from the accumulated stock present when the fishery starts may be appreciably greater than the potential average catch over a period. Probably the greatest average catch would be taken with an effort rather greater than the present (1965), and would be in the range 150-200,000 tons: the potential yields from East Greenland and Faroes may be 30-50,000 tons and 10,000 tons respectively. These estimates only refer to the grounds presently exploited on the continental shelves - down to 200-300 fm. Judging by distribution of larvae there are redfish over the ocean depths which may provide large additional catches.

Other demersal species - plaice, lemon sole, halibut, catfishes (wolffish), ling, tusk - make smaller contributions to the demersal catch, some (e.g. plaice, halibut) supporting specialised fisheries. Most of these show signs of heavy fishing, at least at Iceland (Gulland 1961), and catches could be increased by better management. Such increases would be only moderate, perhaps increasing the total catch of these species from the figures of 55,000 tons in 1965 to perhaps at most 75,000 tons

(d) Herring

The Atlanto-Scandian herring stocks have shown great fluctuations including a long-term cycle of the order of 100 years during the several centuries that they have been exploited. Some of these are certainly due to year-class changes; weak year-classes from 1951 to 1958 led to a decline in catches, which recovered when the strong 1959 year-class recruited to the fisheries. The absolute level of catches in any future year therefore depends more on the (at present unpredictable) strength of year-classes, than on the amount of fishing. Estimates of the stock size of the Norwegian spring-spawning stock from tagging and direct acoustic counting suggests that in the 1950s fishing took about 10-20% of the stock (and thus accounted for about half the total deaths). Fishing effort on this stock has since increased, and it appears that the fishing is at least as heavy on the other elements of the Atlanto-Scandian herring - the Icelandic spring and summer spawners (ICES 1966 a).

It is, therefore, unlikely that any substantial increase in average yield per recruit can be achieved by increased fishing and some minor increase might be achieved by suitable management, e.g. protection of the small fish (now caught in the smasild fishery), or a slight reduction in fishing on the most heavily fished elements. The actual catch will depend on year-class strengths; at recent levels these have resulted in annual catches of around 1.5 million tons.

(e) Capelin

Substantial catches of capelin are taken both at Iceland (50,000 tons in 1965) and northern Norway and USSR (220,000 tons in 1961 and up to ca 500,000 tons in 1967, but only 3,700 tons in 1962). Knowledge of the fishery has been reviewed by Moller and Olsen (1962) and Olsen (1964). The often very large fluctuations in catches are due in part to year-class fluctuations, and partly to changes in the timing and place of the migration to the inshore spawning areas where they are caught. There appears to be very large post-spawning mortality though some fish may spawn twice (Prokhorov 1960), so that fishing has little effect on the stock coming to spawn in the immediately following year. The proportion of the spawning stock taken by the fishery is not known, nor is anything known of the possible stock/recruitment relationships. Olsen (1964) has estimated the abundance of the spawning stock in relative terms, but this cannot as yet be expressed in actual tons of fish.

(f) Other resources

Most of the species caught incidentally when fishing for the other species (cod, redfish, etc.) have already been considered. Probably the biggest resource among trawl-caught fish is the long rough dab, which is caught in moderate numbers (up to ca 200 kg in trawl hauls over most of the area).

Cod is the main large predatory fish in the area. Stomachs of smaller cod contain mainly invertebrates; larger cod also eat invertebrates but also fish - including small cod, capelin, herring, polar cod (*Boreogadus saida*), etc. Most of these species have already been considered above, and the data do not suggest the existence of any large unknown potential. Nor is the probable quantity eaten of capelin or herring (say 10% of 10 times the present production of cod, equals 1 to 1.5 million tons) so very much larger than the present catches of these species as to suggest that they are greatly underexploited.

In the Barents Sea detailed surveys of young fish have been carried out internationally - in 1965 by USSR and Norway and in 1966 and 1967 by USSR, Norway and UK (Anon. 1965, 1966). Though designed primarily for surveying the abundance and distribution of O-group herring and cod, information is given on other species. The surveys were carried out by echo survey, supplemented by pelagic trawling. The 1966 results are presented as charts of the distribution. O-group cod, haddock and saithe were scarce, occurring only at scattered individual stations and were not contoured; herring were more abundant occurring along the north Norwegian coast, and in a few stations near Bear Island and were contoured at one level of abundance. In contrast four species - redfish, capelin, long rough dab and polar cod - were sufficiently abundant over a wide enough area to be contoured at two levels of abundanc O-group fish of some other species were found in smaller numbers - including catfish, *Lumpenus*, *Cottidae* and *Myctophidae*. The results must be interpreted with some caution because of the very great year-to-year fluctuations, at least for some species, e.g. cod, as shown by the USSR surveys of young cod carrie out over the last 20 years. It is believed that the relative scarcity of cod, herring and haddock is due to 1966 being a poor year, likely to lead to extremely poor 1966 year-classes, rather than representing the normal average abundance of these species. The very low strength of the 1965 and 1966 year-classes of cod is shown clearly in the later catches of 1 and 2 year old fish in later trawl surveys (Nizovtsev 1967). Thus, for example, the surveys of cod larvae (in May only) and of O-group fish on the bottom in winter, reported by Baranenkova (1965) for the 1959, 1960 and 1961 year-classes, though not comparable quantitatively with the present surveys, do produce distribution charts looking very like those for capelin, etc. in the 1966 surveys. Comparison of the numbers in 1966 of O-group cod, haddock and coalfish with those of redfish, capelin, long rough dab and polar cod is, therefore, likely to give a misleading impression of the abundance of the latter. More interesting may be a ison of redfish with the other three.

Redfish were by far the most abundant pelagic echo scatterers in the western Barents Sea. This dominance may be compared with the dominance of larval redfish found in the plankton between Newfoundland and Iceland (Henderson 1965), though it is clear that in the present area these young fish come from a stock that is presently exploited. An examination of the quantitative distribution of larval redfish in the south-eastern Barents Sea, and comparisons with the larval numbers in the western Atlantic and with the commercial catches in both areas may give a better measure of the potential new resources, if any, represented by the larval redfish over the oceanic depths. A comparison with redfish, based on larval and O-group catches, may however under-estimate the potential yield of capelin and other species. Redfish are very long-lived, and the fishing mortality to give the greatest long-term yield is likely to be low. Thus the proportion of the stock taken each year for optimum harvesting, and hence probably also the ratio of potential yield/larval or O-group abundance, is small. Also the estimate of potential yield of redfish is not a very precise one.

However, it seems unlikely that the O-group/potential yield ratio differs so much between species, and that the real potential yield of redfish differs so much from its estimated value, that the potential yield of capelin differs by more than an order of magnitude from the figure of 50-100,000 tons estimated for redfish. Therefore, it is possible that 500,000 tons of capelin reported for the Norwegian spring season of 1967 (which was in fact limited by processing capacity, not by catching capacity) may be approaching the potential of the stock. The potential for long rough dab, a quite long-lived species, and for polar cod, are probably rather less than for capelin.

The joint survey also recorded echo traces from larger fish. Apart from the species already considered, adult blue whiting were recorded along the eastern boundary of the Norwegian Sea. No quantitative estimate can be given of the magnitude of this resource.

In the north-western area, there have not been similar published surveys of young fish. Joint echo surveys for herring have covered wide areas to the north and east of Iceland, and apparently most of the traces recorded could be considered as herring (e.g. Malmberg _et al_. 1965, 1966). However, large concentrations of _Micromesistius poutassou_ were found off the east coast on at least one occasion in 1965. Incidental trawl catches have included this species and occasional catches of argentines. Norway pout are common at Faroes, and west and south Iceland(Raitt 1966a, Saemundsson 1949, Kotthaus and Krefft 1957).

There is no comprehensive published survey of the quantitative distribution of eggs and larvae. G.C. Williams (personal communication), in analysing the data collected by Einarsson has found that round Iceland long rough dab eggs and larvae were very abundant, around twice as abundant as any other fish.

These egg and larval data would suggest the presence of four possibly substantial under-exploited stocks - _Gadus poutassou_, argentines, Norway pout and long rough dab. There is no good ground for quantitative estimate, but a rough comparison with other catches suggests that potential yields of each species are probably within an order of magnitude of 100,000 tons.

5.5 North Sea

(a) Separation of stocks

The North Sea is large and partly enclosed; including the Skagerrak there is little interchange to the east (Baltic, Belts). Some fish move through the Straits of Dover, notably the Downs herring which spawn in the Eastern Channel, though spending most of their life in the North Sea. This stock is now small, but analysis of past data should include Channel herring catches in the North Sea; otherwise the interchange at the southern end is probably small enough to ignore.

At the north, deep water and narrowness of the shelf along the Norwegian coast limits appreciable movement of demersal fish along the west of Norway. There is, however, evidence of greater movement of some species, including haddock along the Scottish north coast, and of interchange with stock there, and to the west of Scotland, but in total this is not a large proportion of the North Sea catches or production. Movement of pelagic fish is probably much more extensive. Catches of Atlanto-Scandian herring along the Norwegian coast have been included in past statistics of the North Sea fisheries, but should be excluded from consideration of the production of the North Sea. The past statistical data for herring (probably also mackerel) should be, therefore, treated with care.

Within the North Sea populations of most of the important species can be divided into two or more distinct stocks, e.g. herring (Cushing and Bridger 1966), plaice (de Veen 1962), sole (ICES 1965 a), cod (Bedford 1966) and whiting (Knudsen 1965, Hannerz 1964). For herring, it is clear that the major stocks must be assessed separately, but for the others, or at least the plaice, it is possible that there are sufficient similarities in the pattern of exploitation for the stocks of each species within the North Sea to be treated as a single unit (Gulland 1968).

(b) Flatfishes

Plaice - very good knowledge. "Overfished" in the 1930s but fishing in terms of both total effort and effective size at first capture probably now gives close to the greatest average annual yield, which is about 100,000 tons. Total production is limited more by numbers of recruits than by supply of food to adults, judged by the moderate changes in growth with changes in stock abundance (Wimpenny 1953, Beverton and Holt 1957, Gulland 1968).

Sole - very good knowledge. Fishing is probably close to optimum. Actual yield subject to fluctuations, and tending to increase over the past 50 years (ICES 1965 a). Potential average annual yield is 15-20,000 tons.

Dab - moderate knowledge. There is no fishery specifically for dabs, which do not grow to a large size. Any extension of fishing for small dabs would almost certainly involve destruction of small plaice, and an overall loss in yield. Much of the production going into dabs is, therefore, inaccessible at present, though this production is probably very much larger than the reported catches (ca 6,000 tons). (Fishermen often suggest that scientists should kill off the dabs to give a better production of plaice).

Other flatfish (turbot, lemon sole, etc.) - moderate knowledge. Probably in a similar state to plaice and sole, i.e. present catches (16,000 tons) close to maximum.

(c) Gadoids

Cod - good knowledge. "Over-fished" in the 1930s (Graham 1948), less heavily fished now, at least in central North Sea (MAFF 1965), but still apparently heavy, and probably too heavy, fishing on the small cod in some western areas (Bedford 1966, Symonds and Raitt 1966). The average catch could probably be increased by more rational fishing; the 1968 catch (285,000 tons) was, however, much above the recent average, and was probably the greatest ever taken. This high catch was probably due to transient effects, particularly some good year-classes. It is doubtful if even with proper management this catch could on the average be maintained. The potential average annual yield is possibly 150,000 tons.

Haddock - good knowledge. Has undergone long-term fluctuations (e.g. the catch declined from over 200,000 tons in 1920 to 50,000 tons in 1950, due mainly to a drastic reduction, probably from natural causes, in the stock in the southern part of the North Sea). There are also large flucuations in year-class strength, a recent (1962) year-class being outstanding, giving the near-record catches of 270,000 tons in 1966 (Jones 1966). Better management, especially better protection of the young fish, e.g. by a larger mesh size, would increase the average catch, probably by between 40% and 100% (Parrish and Jones 1953, ICES 1957). The greatest average sustainable yield might be 100-200,000 tons, but the catch in one year, or over a short period might be very different. Reduction of growth rate for strong year-classes suggests that haddock are using a good proportion of the available food (Beverton and Holt 1957), but by no means all of it (see section 6.2).

Norway Pout (Trisopterus esmarkii) - some knowledge (Raitt 1966a). Fishery based on one or two year-classes, with no clear evidence of the effect of fishing. Catches have fluctuated, with peak in 1963 (185,000 tons) with 1965 catches under 70,000 tons. (Some at least of these fluctuations are due to effort changes (Raitt 1968)). No useful estimate of potential yield. There seems, on the basis of very few years, to be negative correlation between year-classes of Norway pout and haddock.

Saithe (Coalfish) - moderate knowledge. Generally, at least until recently, less heavily fished in Northeast Atlantic than cod or haddock, but signs of fishing now becoming apparent (ICES 1965). Probably moderate further increase in catches possible; possible yield perhaps 100,000 tons (North Sea stocks probably closely linked with west of Scotland and Norwegian coast stocks).

Whiting - moderate knowledge. Probably moderately to heavily fished, and only moderate increase in catches possible. Yield perhaps 150,000 tons.

Other large gadoids (hake, ling, pollack, tusk) - moderate knowledge. All probably moderately to heavily fished, some slight expansion in catches possible. 1965 catches: hake 3,600 tons, ling 10,500 tons, pollack 3,200 tons, tusk 2,500 tons, total 19,800 tons. Potential yield is perhaps 25,000 tons).

Other small gadoids (blue whiting, pout whiting) - some knowldge (Raitt 1966). Present catches for meal are probably a small fraction of potential yields, though the main potential is outside the North Sea.

(d) Other demersal species

There is a poor knowledge of any of these. Several species (catfishes, anglers, redfish, etc.) are caught in small numbers by trawl, and by analogy with cod, haddock, etc., are probably heavily fished. 1965 catches were catfish 1,800 tons, anglers (monk) 4,700 tons, redfish 500 tons, breams 200 tons, total 7,200 tons. The potential annual yield of all these combined is probably less than 10,000 tons.

Gurnards occur frequently in small numbers in trawl catches; landings are probably only a fraction of actual catch. Like dabs, they are not very attractive commercially in some countries for human consumption, nor do they occur in sufficient concentrations as a basis of industrial fishery. The potential yield is much higher than the 700 tons landed.

Sandeels - moderate to poor knowledge. Fishing is very localised, and in small areas the effect of fishing can sometimes be detected, but the present fishery covers only a part of the whole North Sea (Macer 1966). The potential yield is probably considerably greater than the present catches of 100-150,000 tons.

(e) Pelagic fish

Herring - moderate to good knowledge. There is considerable scientific argument about the precise state of the stock particularly regarding the long-term effects of fishing; but fishing clearly is a major cause of mortality in the stocks in the southern North Sea, though it is not agreed by scientists whether it has also affected the recruitment. With the recent increased fishing in the northern North Sea, the fishing effort on the stocks has probably approached or passed the level where any further increase in effort will give no appreciable increase in the average annual catch. Catches reached a peak of 1.23 million tons in 1965, and have since declined. The potential yield is probably less than 1.5 million tons, perhaps 1.0 million tons. It should be noted that the stock of herring spawning in the southern North Sea and eastern English Channel, which used to provide catches of over 200,000 tons, has declined to negligible proportions. If this stock does not recover, the total North Sea potential will be reduced. Year-class fluctuations are less important than in the Atlanto-Scandian herring.

Sprat - moderate knowledge. Fishing is localised and coastal. The recent increase in catch (75,000 tons in 1965, compared with 21,000 tons in 1953) seems due in part to a real increase in stock or at least the availability to the fishermen. In some areas, e.g. Wash, the stocks are moderately heavily fished, but in others a large increase in catch may be possible. The potential yield is almost certainly subject to wide natural fluctuations, but under present circumstances is probably at least 150,000 tons. Estimates from egg surveys (Johnson personal communication) of the stock size in the North Sea is from 65-650,000 tons. The potential yield might be half this.

Tunas - moderate knowledge. Only bluefin caught, and only in small quantities; potential yield not more than a few thousand tons.

Mackerel - moderate to poor knowledge. The Norwegian purse-seine fishery expanded very rapidly from almost nothing in 1963. Catches reached a peak of 865,000 tons in 1967 and declined in 1968. These catches came from an accumulated stock of a number of age-groups, and the data so far are not inconsistent with the estimate of 550,000 tons derived in a later section from egg and larvae data. The stocks were certainly under-exploited before 1963.

Horse mackerel - poor knowledge. Present landings of 5,000 tons probably well below the present catch, because of discards, and even further below sustainable yield. This fish is rarely sought deliberately by the fishermen.

(f) Others

Dogfish, skates, rays, etc. - variable knowledge, good for picked dogfish. The northern stock of dogfish (which is caught also in west of Scotland and Norway coast areas) is over-exploited. Probably by analogy with cod and plaice the other species of commercial importance which are mainly caught by trawl are also heavily exploited. Because of the small number (3-15) of young produced per female the dogfish stocks are particularly susceptible to over-fishing (Holden 1967). The potential yield from all these stocks is probably not much, if at all, larger than present catches (36,000 tons) - say at most 50,000 tons.

Unsorted and unspecified - some 150,000 tons of unsorted fishes were landed in 1965. Most of these were herring for industrial purposes.

(g) Other evidence of resources

The most recently published results from trawl surveys are by Sahrhage (1964), giving the results of surveys in the summers of 1959 and 1960 (results of surveys in the winters of 1962 and 1963 will be published late in 1967). The distribution and abundance of the major commercial species agree well with the data from commercial catches, but certain species occurred in quantity in the survey, but not in the commercial landings. The most frequent were as follows:

Long rough dab (*Hippoglossoides platessoides*) - catches of several thousand per haul north of the Dogger.

Blue whiting (*Micromesistius poutassou*) - large numbers (up to 3,000 fish per haul) along the edge of the Norwegian deep water.

Argentines (*Argentina silus* and *A. sphyraena*) - up to 1,000 fish per haul in northern North Sea (north of 57°).

Horse mackerel (*Trachurus trachurus*) - up to 2,300 fish per haul in southern area (south of 56°N), and smaller numbers along the Scottish coast.

The surveys also confirmed the considerably greater abundance of gurnards than is suggested by the small quantity landed. Scottish research vessel surveys in the northern North Sea agree with this list of species, but show common dab and gurnard as also common (Parrish - personal communication).

Though no full echo survey of the North Sea has been published, both research and commercial vessels run their echo sounder while working or on passage in the North Sea and there has been no suggestion of any substantial quantity of traces which cannot be ascribed to the well known pelagic species - herring, mackerel, etc.

Extensive data are available on egg and larval distribution, including a few general research surveys, special surveys on certain species (especially plaice), and plankton recorder surveys.

In qualitative terms these show that the abundant species are either the fish (herring, cod, haddock, plaice, etc.) which have long been exploited for human consumption, or the smaller fish (sandeels and *Trisopterus esmarkii*) for which special fisheries for industrial purpose have recently been developed. No large quantities of eggs or larvae have been found of species which are as yet not exploited.

Further analysis of these data is desirable to determine a quantitative relation, if only rough, between eggs or larvae and sustainable yield. Henderson (1961) gives data on the distribution of larvae in plankton recorder catches round the British Isles (excluding the Irish Sea and English Channel). These data are summarised in Table B1, which also gives data on catches in 1965. The data are in the form of average number or larvae per sample within each area. Assuming perfect filtration each sample corresponds to 3 m^3. The size of most areas was 1° lat. by 2° long., i.e. approximately 4,000 n.mi^2 or 14,000 km^2. The data give the distribution of larvae at 10 m (the depth of sampling), and if it is assumed that the larvae are equally distributed down to 100 m, then the number per m^2 will be $\frac{100}{3}$ x number per sample, i.e. the total number in each area will be equal to:

$$\text{number per sample } \frac{100}{3} \times 14{,}000 \times 10^{6} = 4.7 \times 10^{11}$$

(more precise estimates may be obtained by correcting for different sizes of the areas and using different estimates of the depth to which the larvae are distributed). Plates XXX to XXXIII of Henderson's paper can now be used to estimate the mean number of larvae present during the year (except for *Stomias boa ferox* and *Gadus poutassou* which are mean numbers present in March, April and May), by adding up the numbers in each area.

These figures are given in Table B1 (the clupeoids to the southwest of England were presumed to be pilchards, and elsewhere herring and sprat, and the figures for *G. poutassou* and *S. ferox* have been divided by four to correct for being present for only one quarter of the year), expressed as average numbers present in the area. Also given are the 1964 catches from the area (Regions IV, VI and VII of ICES), and the tons caught per 10^9 larvae.

Table B1 - Catch of fish and estimated number of larvae from the waters round the British Isles

	Larvae x 10^{-11}	Catch ('000 tons)	Tons per 10^9 larvae	Notes
Clupeoids	118.9	1,451	122	
(Herring and sprats)	104.9	1,448	138	
(Pilchard)	14.0	3	2	Not fished intensively in area
Ammodytes	73.7	129	18	Only fished in southern North Sea
Mackerel	57.4	112	20	Lightly fished - recent catches much larger
Micromesistius poutassou	41.1	-	-	Not fished
Coalfish	12.4	74	60	Catches could probably be increased
Common dab	8.2	5	6	Not exploited; only large specimens among incidental catches landed
Whiting	6.8	137	201	
Plaice	6.4	120	188	
Stomias boa ferox	4.6	-	-	Not fished
Witch	2.3	2	9	
Cod	1.9	158	832	Larvae probably underestimated
Lemon sole	1.0	11	110	

For most of the species believed to be fully exploited catches are fairly constant in the range 100-200 tons per 10^9 larvae. This relation suggests sustainable yields of 300,000 tons of blue whiting, 350,000 tons of sandeels, and 550,000 tons of mackerel. Most of the larvae of blue whiting and mackerel were outside the North Sea.

Taken together the various data suggest that apart from certain species (horse mackerel, blue whiting, etc.) occurring mainly at the boundaries, including macrurids and others in the deep water (ca 500 m and deeper) in the north, which may be best considered in other areas, there are no major unexploited species in the North Sea. Catches and landings of some species - sandeels, long rough dab, gurnard - might be expanded.

(h) Molluscs and crustaceans

In 1965 the catches from the North Sea were 70,600 tons of crustaceans (including 47,800 tons of shrimps), and 150,000 tons of molluscs (including 135,000 tons of mussels). Virtually the whole catch is taken in coastal waters and may be considered separately from the production of the main, offshore, part of the North Sea. Knowledge of offshore resources from benthos surveys is comparatively good; none of the numerous molluscs seems at present commercially attractive, and the only attractive crustaceans are Pandalus borealis (in deep water) and Nephrops. 1965 catches of these species were 15,000 tons, and are probably capable of moderate expansion, possibly to 50,000 tons. These resources are considered in detail in separate chapters.

5.6 Waters to the west of the British Isles

(a) Stock separation

The physical characteristics of the region do not provide clear boundaries to the stocks. There are significant interchanges with stocks both to the north, round the north of Scotland (certainly for haddock, and probably other demersal stocks - but not Norway pout (Raitt 1965) - dogfish, and to some extent herring), and to the south (e.g. the adult pilchards found in the English Channel in the summer may migrate from south of Ushant). Interchange with the North Sea through the Straits of Dover does not seem to be large - North Sea herring move into the eastern channel to spawn and there is some movement of small local stocks of demersal fish, e.g. cod (Bedford 1966) and of pilchard and anchovy into the North Sea in summer. Within the region some divisions of stocks are known - most of the fish stocks in the Irish Sea seem to be separate from those outside - but for most species the possible stock separation in the area open to the Atlantic from the north of Scotland to Ushant have not been studied in detail. The statistics for this region are also not as good as in other parts of the ICES area; as noted earlier part of the Spanish catch recorded in Regions VIII and IX probably comes from this region. Also there are some doubts about the precise location of some other catches and generally poor statistics of fishing effort. Mainly for these reasons there are few good assessments of the stocks in this region.

(b) Demersal stocks

The hake was studied in detail by Hickling before and just after the war (Hickling 1927, 1946), who showed that it was over-fished. Subsequent events have done nothing to throw doubt on this conclusion, though detailed analysis has been difficult because of statistical shortcomings. Average catches could be increased by suitable management measures (less fishing, and better protection of small fish), probably to appreciably above the present level. The latter is now known. Reported catches from the region (excluding Spain) were, in 1965, 20,000 tons. If Spanish catches were as much again, this would suggest potential average catches of 50,000 tons.

The major haddock catches in the region come from the West of Scotland. These include an element of fish moving from the North Sea (Jones 1959). A recruitment of larger fish from the North Sea may account in part for the rather larger size of haddock from the westerly grounds compared with the North Sea (e.g. ICES 1964), but the difference may also in part be due to less fishing on these grounds as well as possibly to a faster growth. Changes in catch per unit effort of haddock by British vessels during and just after the war did not fit in with expected changes in a heavily fished stock, though changes in fishing tactics, following the recovery of the hake stocks, may have had an important effect. Probably the west coast haddock is less heavily fished than the hake, or the haddock in the North Sea. However, in view of the local concentrations of Scottish seiners inshore, which fish mainly for haddock, it is unlikely that the stocks are not at least moderately heavily fished. Probably, therefore, the average catch of haddock from the West of Scotland grounds could be at best only increased to a moderate extent, though it is not known whether this would require a restriction of fishing, or a moderate expansion. Recent catches are, as in the North Sea, very high because of the outstanding 1962 year-class. Potential annual catches from average recruitment are probably around 15,000 tons.

In the other areas of the region where haddock are caught (south and west of Ireland), even less is known of the state of the stocks. There is no intense local fishery corresponding to the Scottish seining in the Minches, so probably the effect of fishing is less. Probably, therefore, average catches could be increased by greater fishing.

The cod fisheries are probably in a similar condition regarding both exploitation, and state of knowledge, as the haddock. As judged by tagging returns (53% recapture) (Beverton et al. 1959), the fishing intensity in the Irish Sea is at least locally very high. Potential average annual catches are probably not much above the present - say 50,000 tons - and to catch this would require about the present effort.

The whiting fishery in the north-western part of the Irish Sea has been studied in detail by an international working group - the only one to date which has dealt with problems of stock assessment in this region (Garrod et al. 1966, Garrod and Gambell 1965). They showed that in the local County Down fishery, fishing is so intense that total catches would be increased by the use of a larger mesh size. However, this is only a local fishery, mainly on immature fish. The mature fish move out of the area and the fishing mortality on the mature stocks is not known, nor is the proportion of the total recruitment to the adult stocks coming from the County Down fishery. Thus it is possible that the average total catch of whiting might be increased by more fishing on the adult fish - though these appear to be more dispersed than the immature, and less able to support an economic fishery - combined with some regulation of the immature fishery. Similar considerations probably also apply to other parts of the region – there is an intense fishery in the Clyde which corresponds to that off County Down (Garrod and Gambell 1965). In this area too the absence of old, large fish from catches is believed to be due as much, if not more, to emigration as to heavy local fishing. This suggests that catches of the larger fish, which are probably dispersed in the Irish Sea and to the west of Scotland, might be increased.

There is no suggestion of major unexploited stocks, though most probably catches to the west of Ireland could be increased. Probably the potential average catch is slightly above the present – say 50,000 tons, with overall not much change in effort, though more on the older fish and less on the younger would be necessary.

The saithe (coalfish) caught in the northern part of the region are connected with the stocks further north. Except that there is no local purse-seine fishery for medium-small fish, similar remarks apply; the average catch would probably be increased by increased fishing, but probably not to any great extent (say to 30,000 tons).

Ling, though mainly caught incidentally by trawlers, is probably at least moderately heavily fished, with no great potential increase in the average catch.

Various flatfishes (lemon sole, sole,turbot) are caught in moderate quantities throughout the region. Though not studied in detail, there is some evidence that these stocks are moderately heavily fished.

Williams (1965) found percentage returns of soles tagged in the Irish Sea (17%) and Bristol Channel (12%) which are not much less than the 17–23% found with similar tags (Peterson discs) in the heavily fished North Sea (Williams 1963). It is improbable that the present catches of flatfish (33,000 tons in 1965) can be greatly increased – possibly to 40,000 tons, by increased fishing on some stocks and better management of others.

Several other demersal fish are caught in small quantities. Spiny dogfish probably come from the stock as the North Sea (see above); stocks of conger eel and angler(monk) are probably small; the sea bream probably are connected with stocks further south and will be discussed later.

(c) Pelagic fish

The herring fisheries to the west of Scotland have been reviewed most recently by Saville *et al.* (1965). They found no clear evidence of heavy fishing, and concluded that much of the fluctuations of catches between 27–108,000 tons before the war, and 33–78,000 since the war, were due to changes in effort and not in stock. Surveys of adults and larvae by British research vessels have suggested quite a large stock in this area. The total number of larvae found (Wood 1968) in October 1965 (1.76×10^{12}) was about the same as found in the southern North Sea in 1947–8 when catches in that area were about 200,000 tons, not including catches from the same stock in the central North Sea. In addition to these autumn spawning fish, there is a spring spawning group about one-quarter as abundant (Wood - personal communication). Average catches in this area, including the grounds to the west of the Hebrides, can almost certainly be increased by more fishing, possibly to around 200,000 tons.

Burd and Bracken (1965) have studied the Dunmore stock off southeast Ireland, and concluded it is heavily fished, with a potential annual catch of 12–15,000 tons. The herring stocks in the Irish Sea are probably in a similar state, and not much more than the present catch, i.e. ca 10,000 tons, can be taken. It is not known whether the present very small catches from off the west coast of Ireland can be increased.

The mackerel stocks are related to those supporting the rapidly developing Norwegian fishery in the northern North Sea, and any catch in the present region would to some extent be at the expense of the potential yield in the North Sea. The same probably also applies to the pilchard which migrate into the English Channel (and sometimes also the southern North Sea) from southern waters. Sprat catches are at present small, but could be appreciably increased.

(d) Other evidence of resources

Incidental catches, by trawlers and others, of fish other than those now mainly exploited are not common in shallow water, less than ca 200 m. In deeper water a wide range of species are caught, some in fair quantities. These include fish which might reasonably be used for human consumption – argentine, breams, etc., as well as less attractive fish – macrurids, etc. Since, at these depths (betwen say 200 and 1,000 m) the bottom slopes steeply, the total area concerned, and therefore probably the potential yield is not great.

Besides bottom fish, echo traces in mid-water, probably of fish, are frequent along the edge of the continental shelf, and over the oceanic banks from the Shetlands to southwest of Ireland, though no detailed surveys appear to have been made. Some may be of herring, but other possible species include blue whiting (*M. poutassou*), mackerel, argentines, *Gadiculus* and myctophids, etc. Blue whiting appears to be the main food of the hake (Hickling 1927), particularly medium hake. Larval studies (see section 5.5 on North Sea), suggest sustainable yields of 300,000 tons of blue whiting from the area to the west of Scotland and Ireland. Some research trawling for this species has been done (Raitt 1967). Not as much is known of the more southern area west and southwest of Ireland. More species occur, but more are acceptable to and used by the French and Spanish vessels fishing this water, than to the British trawlers, which mainly fish further north. Probably there are lightly exploited stocks, but no more than further north.

In the shallower areas - between the Hebrides and the Scottish mainland, in the Irish Sea and Bristol Channel - there is less evidence of unexploited stocks of moderate sized fish. Stomach contents of larger fish, some data on incidental catches and egg surveys suggest that the most promising stocks are sandeels and sprats. Johnson (personal communication) estimated from sprat egg surveys that there were 30-55,000 tons of adult sprats off the south coast of Ireland in 1959-60, and 65-650,000 tons in the North Sea, and possibly as much again in other British waters. The biggest catches of sandeel larvae in the plankton recorder surveys (Henderson 1961) occurred off the north coast of Scotland, and in the northern approaches to the Irish Sea (the Irish Sea itself was not included in the plankton recorder surveys). The estimation of potential catches from larval catches by plankton recorder data has already been discussed for the North Sea. The resources of some species may be under-estimated by this method. For instance, argentines, or silver smelts (*Argentina* spp.) have bathy-pelagic eggs, which do not appear in surface hauls, though there may be a considerable resource (Wood and Raitt 1963), and Russian trawlers have reportedly been fishing for argentines in 1967. Danish vessels have also been fishing for Norway pout off St. Kilda (Raitt 1968).

In the English Channel a survey of pilchard eggs was carried out by Cushing (1957), who estimated that there were 10^{10} mature pilchards in the Channel. He assumed a mean length of 20.5 cm, which, using Lopes (1963) data, corresponds to a weight of 65 gm; the weight of the stock can thus be estimated as 650,000 tons. Bridger (1965) carried out extensive studies of the possible development of pilchard fishing in the southwest approaches to the Channel, including the detailed echo surveys. Most of the identified traces were of pilchards, but horse mackerel, anchovies, sprats and garfish were also found.

As a first estimate of the potential yield from this stock, which as adults is virtually unexploited, a figure of 0.4 x M x standing stock might be used. M, the natural mortality coefficient, is not known; fish up to 10 years old are found (Bridger 1965), which suggests a value of M of around 0.5. This gives a potential yield of 130,000 tons.

5.7 Baltic and adjacent areas

(a) Separation of stocks

The fish in the Baltic proper form clearly separate stocks from those in the North Sea, but those in the Belts are intermediate and probably mix to some extent with those in the Kattegat.

(b) Demersal stocks

The state of the demersal stocks in the Baltic was reviewed by an ICES special scientific meeting in 1957. The conclusion was that the demersal stocks (cod, plaice, flounder and dabs) were all heavily fished (see ICES 1959, especially papers by Jensen, Kändler and Thurow, Mulicki, Rutkowicz, Otterlind, Dementjeva, Zemskaya). This conclusion has been supported by later investigations, e.g. Bagge (1966) and Cieglewicz (1963) found high fishing rates on flounder from tagging, and Otterlind (1967) and Jensen (1967) observed a decline in the average age and size of cod.

The actual yield depends very critically on environmental factors. Thus the vast increase of cod catches from the low level of the 1920s to well above 100,000 tons seems due to the greater salinit especially on the spawning ground and the same changes have reduced the flounder stocks (Dementjeva 1963, ICES 1959). Short-term predictions may be made from environmental conditions (Oyaveer and Rannak 1967), but unless environmental conditions can be predicted, such forecasts can be made into the future for at most the average lifespan of the individual fish. On the assumption that there are no major changes in the environment, then the potential catches, with the proper management measures, such as those outlined by ICES (1959), in force, the potential average annual catch from Region III is rather above the present (1962-5) level, e.g. 200,000 tons of cod, and 50,000 tons of various flatfishes (mainly plaice and flounders).

(c) Pelagic fish

No detailed analysis of the effect of fishing on the herring or sprat stocks appears to have been published. Analysis of statistics is made difficult by the absence of USSR, Polish and East German catches from many of the volumes of the ICES statistics. Also small herring and sprat are not always kept distinct (Elwertowski and Popiel 1963). There are some signs of heavy fishing, e.g. decline in catch per trap-net in the Gulf of Parnu coinciding with an increase in the number of traps (Dementjeva 1957). Possibly not much further increase in average catch can be achieved, but detailed studies are required. As for the demersal catches, the actual catch in any future year depends on environmental factors; recent catches have averaged 275,000 tons; the potential average catch may be 300–400,000 tons. Lishev and Usars (1967) considered the interaction between cod and sprat herring. There are significant negative correlations between the catches, particularly between the catch of cod, and the catch of sprat in the following year. This is believed to be due to predation by cod – sprat makes up some 30% (by weight) of the food of cod over 26 cm. The estimated weight of sprat eaten, apparently by those cod which were subsequently caught in the Soviet Gotland fishery, was some 46,000 tons annually. The total consumption must be much higher, probably of the same order as the total sprat catch. The intense cod fishery presumably, therefore, has some beneficial effect on stocks and catches of sprat and also herring, though the effect on catches cannot as yet be measured quantitatively. There is no evidence that the fishery for sprat or herring has any measurable effect on cod stocks or catches.

(d) Other resources

There are no indications of large stocks of fish of species other than those already exploited. Echo surveys by Lindquist (1964) off the Swedish west coast revealed no traces other than those believed to be sprat, or small herring. There are resources of molluscs and crustaceans, but these are considered in separate chapters.

5.8 Southern waters

(a) Demersal fish

The population dynamics of the demersal stocks in this area (from Ushant to the Strait of Gibraltar) have not been studied in such detail as those further north. To some extent this is due to shortcomings in the statistics (little data on fishing effort and inadequate data on area of capture). As noted above (section 5.5) some of the catches recorded in the Bulletin Statistique as coming from this area in fact come from the grounds to the west and southwest of the British Isles.

Hake is the most important demersal species. The stocks have probably been heavily fished for a long time (Letaconnoux 1951). Very small hake are caught in some areas – Meriel-Bussy (1966 a) reported a modal length of 10–14 cm on catches in November, and Rodrigues et al. (1963) found a mode 15 cm, and about 25% by number of "non-commercial" hake in experimental trawling in the Bay of Biscay. This may be contrasted with a modal length of 50–60 cm in the landings at Fleetwood by English trawlers fishing to the west of Scotland. Since the growth of hake in the two areas is not vastly different (Meriel-Bussy 1966), a difference of length of four times, and in weight of perhaps 50 times – and even more in value – shows that the benefit from adequate management of the hake stocks could be very large. The difference between catches by different groups of vessels landing at La Rochelle is shown clearly by Meriel-Bussy (1967). The deep-sea trawlers land approximately equal quantities of five out of the six size categories, but few of the smallest size; the landings by small vessels (artisans) contain some 60% of the smallest categories, while the short-lived gill-net fishery, apparently based on a limited stock of old fish (Quero and Meriel-Bussy 1967) consisted of 90% of large hake. The potential yield is difficult to estimate with any precision. The recorded catch in 1965 from ICES Regions VIII and IX was 95,000 tons but some of this (perhaps, as suggested in section 5.5, 20,000 tons) was in fact caught further north so that the real catches might be only 75,000 tons. The potential catch is likely to be substantially bigger, and may well be 100,000 tons, but probably not very much more.

The other important demersal species (breams, flatfishes, etc.) are probably also heavily fished. Letaconnoux (1948) found after the war a big increase in the catch per hour of trawlers fishing out of La Rochelle for nearly all species; however, the area of fishing was not given in detail, and was probably at the northern edge of the present area, and including part of ICES Region VII. There is no reason to suppose that the catches of those species presently exploited can be increased substantially; any increase is more likely to result from better management than from increased fishing.

There is little evidence concerning possible demersal stocks other than those at

Rodrigues et al. (1963) gives data of catches with small meshed trawls in the southeast corner of the Bay of

Biscay; the major species were hake, pout (*G. luscus*), blue whiting (*M. poutassou*), angler, squid and octopus.

(b) Pelagic fish

The most important pelagic species is the sardine (pilchard). The available statistics up to 1956 have been reviewed by Riedel (1960). The total catch has fluctuated between 150-220,00 tons since 1940 - and probably in the same range since at least 1927 if allowance is made for the Spanish catch, the statistics of which were not available for the period 1927-40. Riedel believed that the fishing effort, in terms of manpower, boats and general technical progress, has increased over the period; the lack of any appreciable increase in total landings indicated that the level of effort in the 1920s and 1930s represented a balance between fishing input and abundance (i.e. gave not much less than the maximum average annual catch). Since 1956 there has in fact been a slight increase to between 220-250,000 tons in the total sardine catches - mainly from Portugal, while the French catch has tended to decrease. There have not been more recent published studies concerning the effect of fishing on these stocks, but it appears that Riedel probably under-estimated the potential yield, which is likely to be at least 250,000 tons, and might well be higher.

The ICES statistics include some 100,000 tons of various clupeoids; some of these may be sardines, but the total includes anchovies, and possibly a few sprats. Horse mackerel (ca 100,000 tons) and mackerel (ca 30,000 tons) are also important, but for none of these species are there published studies on which estimates of the potential yield can be based. It is probable that the former at least are less heavily fished than the sardine, and catches can be moderately increased (see below concerning eggs and larvae).

Tuna (bluefin, albacore and bonito) are caught in the area, but these stocks are being considered in a separate study, dealing with the tuna stocks of the world as a whole. Similar specialised studies have been made of the crustacean, and molluscan resources (see relevant chapters).

(c) Eggs and larvae

The distribution of these in the Bay of Biscay during 1964 has been described by Arbault and Boutin (1967). Four surveys were made with a Hensen net in February, May, August and November. By far the most abundant larvae were sardines; anchovy eggs were as abundant as sardine eggs, but anchovy larvae were comparatively scarce. Eggs and larvae of hake, horse mackerel, dragonet (*Callionymus lyra*) and mackerel were rather less abundant - of the order of one-tenth of the abundance of sardines and anchovy. Other species were even less abundant. This suggests that there are no important stocks other than considered above. Also, the low number of eggs and larvae of horse mackerel and mackerel relative to sardines suggests that either the potential of these species is not much greater than the present catches, or that the potential of sardine is appreciably greater than present catches.

6. DISCUSSION

6.1 Summary

The estimates of potential catches made in the previous section have been summarised in Table B2. Question marks, and brackets plus question marks denote increasing degrees of uncertainty in the estimates. Where it is quite impossible to make any reasonable estimate, the probable order of magnitude has been indicated, i.e. x 10, between 10-100,000 tons; x 100, between 100,000-1 million tons

Two totals have been given for each area; the first (A), including only those stocks for which an actual estimate of potential yield (however imprecise) has been given. The second total (B) includes those stocks for which only an order of magnitude figure is available. In calculating these totals (and the relevant species totals) potential catches entered in Table B2 as (x 10) have been taken as 30,000 tons, and (x 100) as 300,000 tons. All totals have been rounded off.

The potential catches in each major area have also been summarised in Table B3. For comparison with estimates of primary production, and of the production at other trophic levels, the species of fish have been classified as zooplankton eaters (the pelagic fish, excluding tuna, squid, sandeels, Norway pout, blue whiting and other small demersal fish) and the rest. This division, denoted in the table as 'pelagic' and 'demersal' is somewhat arbitrary and does not correspond exactly to first and second stage predators. Many of the forms of the zooplankton consumed are predators - euphausids, larval fish, etc., while much of the production of large predatory fish, such as cod, comes from zooplankton consumed when small.

Table B2 - Potential yields from the ICES area ('000 tons)

	I, II NE Arctic	Va, XIV Iceland	Vb Faroes	IV, IIIa North Sea	VI, VII Westerly	VIII, IX Biscay & Portugal	IIIbcd Baltic &Belts	Total	Actual Catch 1968
Plaice	7	10	+	100	10	2	40	170	130
Long rough dab	(200)?	(200)?	(x1)?	(x10)?	-	-	-	400	No data
Other flatfish	50	20	5	60	40	20?	10	200	150(h)
Cod	1,000	525	35	150	50	2	200	2,000	2,010
Haddock	200	75	25	150	15	-	-	465	385
Hake	-	-	-	5	50	100	-	150	110(h)
Saithe	175	100	20	100	30	-	-	425	318
Whiting	-	3	+	150	50	5	-	200	189
Norway pout	-	(x10)?	(x10)?	(100+)?	(x10)?	(x10)?	-	(200)	469(i)
Blue whiting	(x10)?	(x10)?	(x10)?	(f)	(300)?(f)	(x100)?	-	(500)	No data
Other large demersal	50	60	15	30	30	100?	-	300	200 (h)
Redfish	75	200	10	-	-	-	-	300	137
Other small demersal	(500)?(c)	(x10)?(d)	(x10)?(d)	(100)?(b)	(x100)?(d)	(x100)?(d)	-	(1,000)	60(h)
Sandeels	-	(x10)?	(x10)?	(350)?	(100)?	(x10)?	-	(500)	194
Capelin	500+?	(x100)?	-	-	-	-	-	(1,000)	615
Argentines	-	(x10)?	(x10)?	-	(x10)?	-	-	(100)	-
Horse mackerel	-	-	-	(x10)?	(x100)?	150+?	-	(500)	120(h)
Herring	800(a)	700(a)	15(a)	1,000	200	-	250?	3,000	2,283
Pilchard	-	-	-	++	(130)	250+	-	400	200
Sprat	-	-	-	(250)?	(250)?	+	100?	600	140(h)
Anchovy	-	-	-	++	++	(x100)?	-	(300)	No data
Tunas	-	-	-	5?(g)	++(g)	70+(g)	-	70	50(h)
Mackerel	-	-	+	550?(e)	(e)	50+?	-	600	900(h)
Dogfishes	5?	1	1	25	15?	10?	-	60	38
Skates	5?	2	+	20	25?	10?	-	60	35
Squid	(x10)?	(x10)?	(x10)?	(x10)?	(x10)?	(x100)?	-	(1,000)?	5
TOTAL (A)	3,550	1,900	125	3,125	1,300	750	600	(14,000)	9,400(h)
TOTAL (B)	3,600	2,200	250	3,300	1,900	2,000	600		

Notes -
+ Probably less than 1,000 tons
++ Uncertain, but small, probably only a few thousand tons
(a) Atlanto-Scandian herring. A total for all areas of 1.5 million tons is split rather arbitrarily between the regions
Pout whiting, gurnards, etc.
Mainly polar cod (*Boreogadus saida*)
Includes argentines
Mackerel resources of IIIa, VI and VII included in North Sea
Blue whiting resources of North Sea included in VI and VII

Notes - (cont. Table B2)

(g) Discussed in detail in chapter dealing with world tuna resources
(h) Estimated
(i) Possibly included small haddock

Single underlining: moderately heavily fished, but increased fishing likely to give some increase in catch
Double underlining: heavily fished, any increase in catch will come from better management, and not from increased fishing

Table B3 - Potential and actual yields from each area of the Northeast Atlantic, and potential yields per unit area

	Regions							
	I, II NE Arctic	Va, XIV Iceland	Vb Faroes	IV, IIIa North Sea	VI, VII Westerly	VIII, IX Biscay &	III Baltic	Total
Area ('000 km²)	1,300	150	25	600	500	160	420	
Potential catches ('000 tons):								
Pelagic	1,300	1,100	100	2,300	1,050	1,200	350	7,400
Demersal	2,200	1,200	150	1,000	850	800	250	6,650
TOTAL	3,500	2,300	250	3,300	1,900	2,000	600	14,000
Kg/ha:								
Pelagic	10	73	40	38	21	75	8	
Demersal	17	80	60	17	17	50	6	
TOTAL	27	153	100	55	38	125	14	
Ratio:								
Pelagic/ Demersal	0.6	0.9	0.7	2.2	1.3	1.5	1.3	
1968 Catches:								
Pelagic	1,250	116	8	1,978	225	598	110	
Demersal	1,482	721	99	1,368	262	228	300	
TOTAL	2,732	837	107	3,346	487	826	410	

Also shown in the table are the areas of bottom less than 200 m in each area, and the estimated potential yields expressed as kg/ha. If 10% of the weight of fish is carbon, then these figures should be divided by 100 to give the yield as gC/m². They should be divided by 10 to give it as tons/km².

These figures should be treated with some reserve, and have in fact been rounded off to the first or second significant figure, and so may not correspond precisely with additions from Table B2. Some general comments and conclusions may be made.

From north to south (excluding the Baltic) there is a fairly steady reduction in the proportion of demersal fish, relative to the pelagic fish. This may well be related to the nature of the productive cycle, which is very highly seasonal in the north, but more uniform throughout the year in the south.

The magnitude of the potential yield per unit area is quite variable. Some of this variation is no doubt due to errors in the estimates, but some is real. Thus the low figuresfor the Baltic, and probably also the Barents Sea, are due to areas of very low primary production in these regions - the Gulf of Bothnia, and north-eastern Barents Sea. In regions with narrow continental shelves the figures are probably misleading in that much of the fish production comes from primary production occurring off the continental shelves. This may occur to a large extent at Iceland, Faroes and Biscay and Portugal. It is probably less important in the westerly region, despite the long boundary between the shelf and the deep ocean, because much of the fish production occurs in more or less enclosed waters - English Channel, Irish Sea and the Minches. Making allowance for these factors, the consistency between the figures is fairly good.

6.2 Comparison of potential fish yields and primary production

Because of the probability of unknown contributions from primary production from off the continental shelf, as noted above, only for the North Sea and the Baltic may a direct comparison between primary production and fish potential be possible. For the North Sea, this has been reviewed by Steele (1965). His figures for fish yield are slightly different from those derived here. His are of total fish production, not only that part of the production that is, or could be, taken by man. The figures were actually calculated as the weight of fish dying, by multiplying the catch by the ratio of total to fishing mortality; this is clearly equal in a steady state situation to the production of fish of commercial size. This should give an under-estimate of the actual production of fish, because omitted from the calculation are fish which die before reaching commercial size, and fish from unexploited stocks. The analyses here suggest the latter are not very large. However, fish yield, in the sense that he uses it, should be greater than used here because Steele's case refers to the yield to all consumers of fish, not just to man. In even the best managed fishery there must be 'losses' to other predators, disease, etc. Allowing for losses both before and after reaching the optimum size at first capture, the total fish production is likely to be at least 50% greater than the potential yield.

For these reasons, the near coincidence between the estimates of fish yield (0.81 gC/m^2 here, and 0.77 gC/m^2 by Steele) is just a coincidence, especially as Steele used too low a figure (3.3 x 10^5 km^2) for the area of the North Sea, and his yield should be nearer 0.6 gC/m^2. From the assessments made in this report, the fish yield in his sense may be estimated as around 1.2 gC/m^2.

However, the differences are not great when considering the order of magnitude of the difference between primary production and fish yield. In particular the area taken for the North Sea does not affect at all the arguments put forward by Steele.

As he points out, if a 10% reduction is assumed at each trophic level then the production of herbivores is 10% of the primary production (100 gC/m^2/year), and i.e. 10 gC/m^2; working from the other end, the production of the food eaten by the fish 10 times the yield, i.e. 6-12 gC/m^2. On this assumption, if the production figures are right then fish must eat herbivores, and must also be the main consumer of herbivores. Neither of these is true, and the production figures are not likely to be greatly in error. That for primary production might, at the very worst, be too low by a factor of two; the potential fish production must at least be as great as the average recent catches, which, for demersal fish in particular, are not much less than the estimates of potential yield given here. It is interesting that since Steele drew attention to the remarkable constancy of demersal catches over the past 50 years (400,000 tons ± 20%), there has been a rapid increase to 1 million tons in 1966 and 1.3 million tons in 1965. This increase may be due to different reasons in different stocks, but the increase in haddock catches is due largely to the outstanding 1962 year-class. The history of this and other outstanding year-classes of haddock, suggests that at its normal abundance the haddock stock does not fully use its available food resources. There is a reduction in growth in a good year-class, but this is by no means enough to counterbalance the increased numbers. The total weight increment, and presumably also the food consumption, is much greater for strong year-classes.

From this, therefore, it follows that the efficiency of transfer from one trophic level must be more than 10%, or the 12% maximum found in experiments by Slobodkin (1959). Explanations for this have been then suggested by Steele, who, following MacArthur (1955), believes that the efficiency in higher latitudes may be higher because the productive cycle is seasonal. This is important for the present studies of the world fish potential in that estimates of the potential in tropical or sub-tropical waters based on temperate fish potential, and the relative primary production may give too high figures. Regarding the North Sea estimates of fish potential, the comparison with primary production, suggests that probably no large fish potential has been omitted. (It has been drawn to my attention since writing this section that estimates of primary production using the C$_{14}$ technique made in the period 1958-66 are probably too low, and should be increased by a factor of 1.45. This will reduce the discrepancy to some extent.)

In the Barents Sea, estimates of production of phytoplankton made by Russian scientists (Bogdanov personal communication) are of total production of 1.2×10^9 tons, or about 1,000 g/m^2 (net weight). This (assuming 10% carbon) is about the same primary production per unit area as the North Sea, but the estimates of fish production are about one-third – i.e. more nearly in accordance with a reduction of 10% at each trophic level, with the major demersal species – cod, haddock, etc., being three stages removed from the primary production. However, if the efficiency increases with latitude then the Barents Sea should be more productive than the North Sea. Possible explanations include (i) the estimate of primary production is too high; (ii) the estimate of fish potential is too low; (iii) the efficiency in the Barents Sea is lower than the North Sea; (iv) most of the production in the Barents Sea ends in blind alleys – forms such as jellyfish, starfish, etc., which are at present unsuitable directly or indirectly for harvest by man. Some indication that the production of cod is limited by the original primary production is given by the observation of Ponomarenko (1967) that the growth rate of cod has increased, apparently due to the reduced abundance of the present stock. The biggest changes are among the young (less than 4-year-old) fish, which suggests that the supply of food to the older fish is less limiting.

In the Baltic the estimates of production are 34×10^6 tons phyto and zooplankton (Bogdanov personal communication) and 10×10^6 benthos. If fish are respectively 2 and 1 trophic levels removed, and dividing these figures by 10^2 and 10^1 gives a potential fish yield of 340,000 plus 1 million tons. This is well above the estimates in Table B3; the same possible explanations exist as for the Barents Sea of which the possibility of much of the benthos production being unsuitable for consumption by fish seems particularly likely. This emphasises the need for qualitative as well as quantitative studies of production.

6.3 Needs for further study

Too much of the estimates of potential yield presented here are very tentative, so that it is a truism to say that much further research is needed in all the branches of fishery science involved. Certain particular items can be distinguished as needing special attention. These include:

(a) Primary production – a more detailed review of available published and unpublished data, including a review of the comparability of different methods. Further observations in some areas or seasons. Examination of the possibility of using rapid methods of estimating productivity, e.g. from 'greenness' of plankton recorder material (though greenness is a measure of standing crop, not, directly, of production).

(b) Zooplankton and benthos – further studies generally, especially as regards production, as opposed to standing crop.

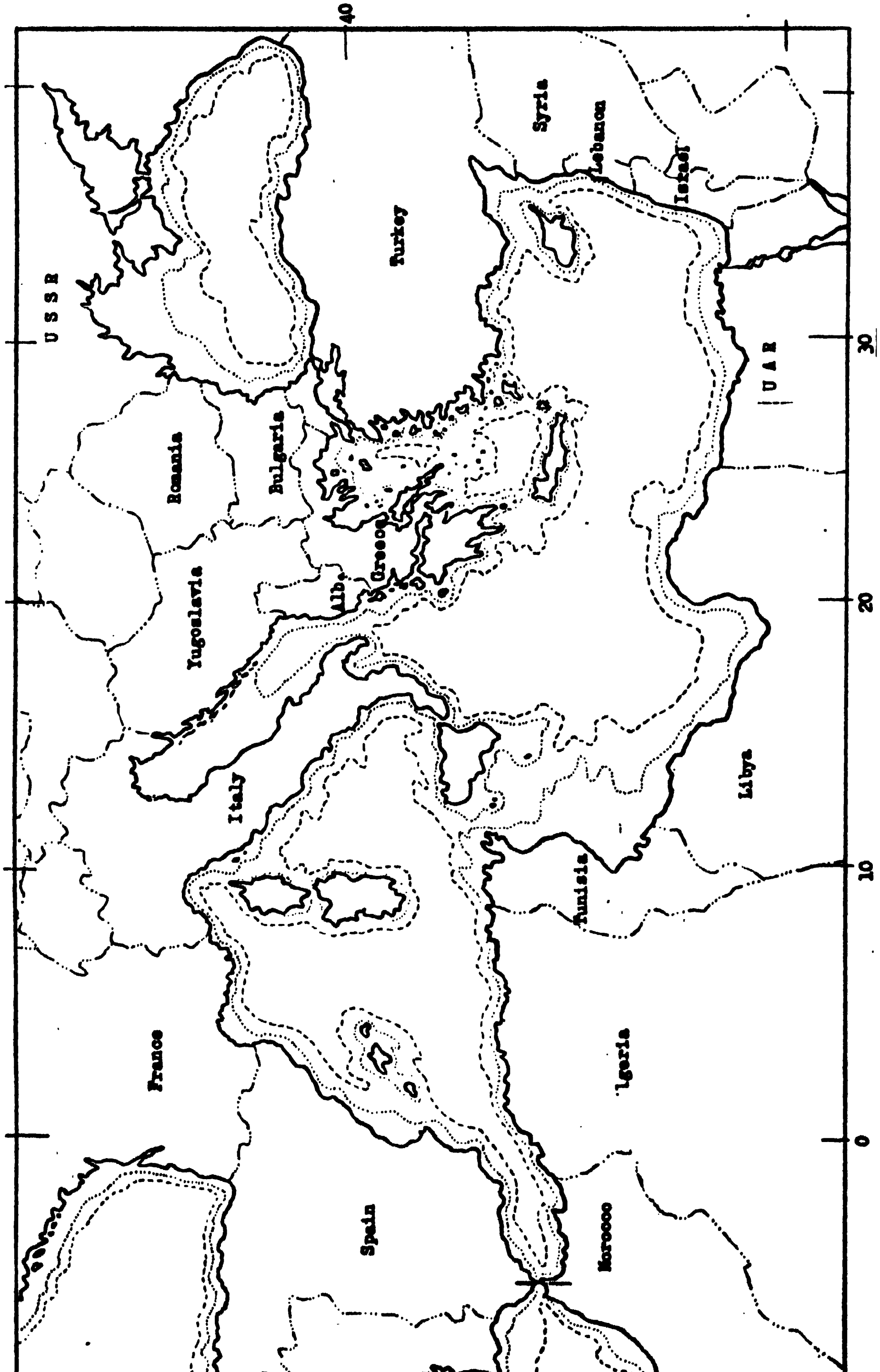
(c) Stock assessment – more studies generally, but particularly for those stocks with long-established fisheries, and which have had sometimes extensive biological research, without explicit stock assessment studies, e.g. sardine.

(d) Eggs and larvae – general studies on the likely precision achieved by using eggs or larvae as quantitative measures of the potential yield. Examinations of the variation of the ratios, standing crop of larvae : standing crop of adults : potential. Do the large numbers of eggs and larvae from some species (long rough dab, oceanic redfish) really indicate large potential? The carrying out, if necessary, in certain areas of surveys of eggs and larvae specifically aimed at stock assessment.

(e) Acoustic methods – further use in appropriate areas of these methods of resource survey.

All the above apply in particular to those stocks/areas where there appears to be a considerable under-exploited resource – blue whiting, argentines, sandeels, capelin, especially round Iceland, horse mackerel, pilchard in the English Channel, sprats to the west of the British Isles, anchovy and squids.

The discussion in the previous section shows that the simple model of food chains in the sea, with two or more distinct trophic levels from primary production to fish, and a 10% loss at each step, gives a poor representation of reality, at least in the North Sea. Also the production of fish, especially demersal fish, may be much closer to the limit of production at the later stages of the food chain set by the total primary production than is suggested by the simpler models of fish population dynamics. These facts are important not only for the present type of study, but also for problems of fisheries management. There is, therefore, an urgent need for further research in this field.



C – MEDITERRANEAN AND BLACK SEA

1. TOPOGRAPHY

The Mediterranean Sea is a large, almost land-locked water mass, which separates the European Continent from Africa and Asia. It is connected to the East with the Marmara Sea and the Black Sea and it communicates with the surface layers of the Atlantic Ocean through the narrow Strait of Gibraltar (till depth 320 m).

The continuity of the water masses in the Mediterranean is broken up by the great variety of land areas in shape, size and mountain systems, some of which have submerged prolongations. A submarine ridge between Sicily and Cape Bon in Tunisia, having a maximum depth of a few hundred metres, divides the Mediterranean into western and eastern parts, oriented along a northwest-southeast axis. Another submarine ridge exists between the Adriatic Sea and the Levantine Basin.

The western part of the Mediterranean has the following three deep basins:

the Alboran Basin, east of Gibraltar, between the coasts of Spain and Morocco;

the Algero-Ligurian Basin, containing the Balearic Islands; it includes trenches more than 3,000 m deep, especially between Sardinia and Minorca;

the Tyrrhenian Basin, located north of the Sicilian Strait, between Italy and the islands Corsica and Sardinia; it has a wide area below 3,000 m.

The eastern Mediterranean has the following deep basins:

the Ionian Basin, with its deep sea floor. A submarine ridge between western Crete and Cyrenaica separates this basin from:

the Levantine Basin, located between the Ionian Basin and the slope of Asia Minor. The Crete Island separates it from:

the Aegean region, situated between Crete Island, the Strait of Dardanelles, the mainland of Greece and Asia Minor. It contains several deeps and troughs, separated partially by rises and ridges;

the Adriatic Sea, between Italy and Yugoslavia, consisting of a shallow northern section, a middle basin with a depth of 200 m and a 1,300 m deep basin in the south.

Except for the Adriatic Sea, all mentioned major sub-divisions of the Mediterranean reach great depths. Generally the coasts are rocky and mountainous, and the continental shelf steep and narrow. There are two major areas of wide shelf - in the northern part of the Adriatic, and off eastern Tunisia. Smaller areas of shelf are off the Nile delta, along the Libyan coast, off Valencia, and in the Gulf of Lions. The total area down to 100 ft (180 m) is about 500,000 km^2.

The Black Sea is formed by a deep oval basin, with a steep and narrow shelf to the south, and two wide expanses of shallow water to the north - the almost entirely enclosed Sea of Azov (38,000 km^2, with a mean depth of less than 10 m) and an open area of about the same extent west of the Crimea. The southern shore is steep, with only a narrow strip of shallow water.

2. HYDROGRAPHY

2.1 Water masses

The hydrological conditions in the Mediterranean are dominated by the presence of three layers of water masses: the surface layer, the intermediate layer and the deep layer, which continues down to the bottom (a separate bottom layer is absent).

The main characteristics of these Mediterranean water masses (Tchernia 1960) are:

(a) the surface layer has a thickness which generally varies between 75 m and 300 m but may be only 30-40 m in the Adriatic. This variable thickness is determined by the presence of a minimum temperature at its lower limit;

(b) the intermediate layer is occupied by warm and saline water coming from the eastern Mediterranean and characterised by temperature and salinity maxima at 400 m depth. The extent of the inflow of this water into the Adriatic varies very much from year to year (Buljan 1953, 1957). This layer is situated in depths of between 300 and 600 m. Over the sill of the Strait of Sicily, the water of this layer has a temperature of about 14°C, a salinity of 38.7°/oo and a sigma-t of 29.04. Salinities over 38.7°/oo exist only south and east of Sicily, but never in the western Mediterranean;

(c) the deep layer occupies the remaining zone between the intermediate layer and the bottom. The approximate temperatures in this zone are: 12.9°C at 1,000 m and 13.1°C at 2,500 m; its salinity is as high as 38.6°/oo in the Adriatic, but generally 38.4°/oo or slightly less (Zore-Armanda 1963). In general, the water of this layer is very homogeneous.

The Black Sea is strongly stratified. The lower level is noticeable for the very low oxygen levels and concentration of hydrogen sulfide. The salinity is moderately low (21-22.5°/oo) and the temperature around 8-9°C all year. This is covered by a layer, 150-200 m thick, of very low salinity water (16-18°/oo in the central part), when temperature ranges from 6°C in winter to 25°C in summer.

2.2 Currents

The circulation on the surface currents in the Mediterranean can be summarised as follows:

(a) The Atlantic waters entering the Mediterranean flow mainly along the African coast, also reaching the eastern part of this sea.

(b) Several branches originate from the main current flowing eastwards: during the summer one off Biserte flows towards the Tyrrhenian Sea; the other diverges off Palermo (Sicily), crossing this Sea. This branch is called the "Central Tyrrhenian Current"; it enters the Ligurian Sea, the Gulf of Genoa and the region off the Riviera. In front of the Hyeres Islands, it sub-divides into two branches, one of which continues its flow along the French and Spanish coast, whilst the other diverges southward, arrives at the coast of Corsica and flows again northward. In this way, it contributes to the formation of a large cyclonic movement.

(c) Between the Balearic Islands and Sardinia, the currents are weak and change their direction frequently, except along the coast of Sardinia, where the current flows south-eastward along the coast of Italy.

(d) During the winter, there appears to be an intensification of currents connected with the eddy existing in the Ligurian Sea. It results from the cyclogenetic trends over the western Mediterranean in this cold season which gives rise to strong easterly winds more frequently than in summer.

(e) In big bays, like Oran, Arsew and Alger, there exists an inverted Mediterranean Current, characterised by salinities of 37.5 to 38.3°/oo.

(f) Part of the Atlantic waters penetrate into the eastern Mediterranean through the straits between Crete and the African coast. In their further course, these waters follow the coast of Levant in cyclonic route and in the neighbourhood of Rhodes they enter the Aegean Sea.

(g) The southern Adriatic is strongly affected by currents coming from the Aegean Sea and partly from the west along the coast of Sicily and the southern coast of the Italian peninsula. There are considerable seasonal changes. The dominant current in summer is outward along the west side, and in winter inward along the east coast (Zore-Armanda 1968, 1969).

Between the Black Sea and the Mediterranean, there is a surface current carrying low salinity water into the Mediterranean, and an under-current of high salinity water into the Black Sea. Within the Black Sea, the general surface circulation along the coasts is anti-clockwise, the strongest elements being along the eastern and southern coasts. These currents form eastern and western gyrals.

Freshwater discharge is important in the Black Sea, and in the Mediterranean the major discharge has been from the Nile; large seasonal variations in the Nile discharge influence the hydrology, productivity and fisheries of the eastern Mediterranean. It reduces the salinity of the coastal waters and increases the stratification. The flood of the Nile occurs between August and November. During these months, the river transports a large amount of suspended particles. The inorganic and organic matter amounted to 4 kg/m^3. Silt particles in the Nile absorb phosphates and nitrates. In contact with the sea water, rapid sedimentation occurs followed by the gradual mixing with the marine waters.

The recently built dams at Aswan will reduce the flow of the Nile waters into the sea which might cause ecological changes of direct influence on the fisheries in this region.

The Suez Canal forms a man-made connection between the Mediterranean Sea and the Red Sea. The exchange of water through the Suez Canal is negligible compared with the exchange through Gibraltar. It is based on warm surface water flowing from the Red Sea into the Mediterranean and colder bottom water moving in the opposite direction.

The general water budget of the Mediterranean is given in Table C1 below:

Table C1 - Water budget of the Mediterranean Sea (Svedrup *et al.* 1942)

Gains	m^3/sec	Losses	m^3/sec
Inflow from the Atlantic	1,750,000	Outflow to the Atlantic	1,680,000
Inflow from the Black Sea	12,600	Outflow to the Black Sea	6,100
Precipitation	31,600	Evaporation	115,400
Run-off	7,300		
TOTAL	1,801,500		1,801,500

2.3 Nutrients

In the Mediterranean Sea, nutrients are scarce and decline in concentration towards the east.

In the western Mediterranean, in addition to the biogenic run-off from the rivers, the influx of Atlantic waters supplies some nutrients. However, the exchange over the sill at Gibraltar constantly withdraws nutrients from the reasonably rich intermediate layers and thus reduces the accumulation of nutrients in deep layers.

Low nutrient concentrations occur in the Aegean and southern Adriatic Seas due to such factors as sporadic run-off, bad drainage, inadequate mixing and over-turn of water masses and limited biological regeneration of nutrient material. Nutrients increase during years of high inflow of intermediate water (Buljan 1953).

The northern Adriatic receives run-off from rivers in northern Italy. While nitrates and nitrites are common, especially in winter, phosphates are always scarce (Cicatelli 1967). The drainage to the eastern Mediterranean, with the exception of the southern sector, is partly from the Black Sea into which flow the major river systems. These rivers, however, have great seasonal variations in the biogenic run-off and thus in the transfer of these elements to the Mediterranean via the Black Sea. Biogenic contributions from the land drainage are extremely small, but contributions from erosion may be significantly more than those from other sources (McGill 1965).

3. PRIMARY AND SECONDARY PRODUCTION

3.1 Primary production

The primary production in the region is generally low, but moderately high in some parts, especially in the Black Sea.

Kondratieva (1965) pointed out that effective potential productivity of phytoplankton in various regions of the Mediterranean may vary from 7 to 157 mg/m^3 in 24 hours. The lowest values have been observed in the Ionian Sea in the Levant (7-21 mg/m^3) while the highest occur in the Adriatic Sea where values as high as 120-364 gC/m^2/year have been obtained by the oxygen method

(Buljan 1969, Pucher-Petkovic 1969). Those values are low in comparison with the Black Sea (106-1,330 mg/m^3). Similar results have been obtained by the chlorophyll and radioactive method. The available data for the upper layer of the Mediterranean (0-50 m) indicate high productivity of the Black Sea, Adriatic, Strait of Gibraltar, and along the coast of Algeria; intermediate values for the Strait of Tunisia and low values for Tyrrhenian, Ionian and Levant Seas.

In general, the primary production of phytoplankton in the Levant is low and may vary from 0.1 mgC/m^2/day to 31.2 mgC/m^2/day (Oren personal communication). The production of the Western Basin is higher. McGill (1961) estimated that in Monaco it varies between 31.5 to 42.0 mgC/m^2/day.

3.2 Zooplankton

Quantities of zooplankton appear to be smaller in the Mediterranean Sea than in the North Atlantic. Gilat *et al.* (1965) studied zooplankton in the Ligurian Sea (western Mediterranean) and compared the results with those obtained in the Northwest Atlantic and the Indian Ocean. Monthly average displacement volumes (cm^3/1,000 m^3) are given which indicate that the Ligurian Sea produces less zooplankton than the other two areas.

In the Ligurian Sea (Roquebrune Bay) the volume of zooplankton varies between 18.3 (in February) and 361.7 (in May). It has been found in the same area that the zooplankton biomass decreases considerably from the surface into the deeper waters. There is, however, a possibility that higher concentrations occur in certain deep layers since scattering layers have been recorded in some cases.

A spring peak (March-May) of zooplankton abundance has been observed in various sections of the Mediterranean; volumes up to 830 cm^3/1,000 m^3 were recorded (Gilat *et al.* 1965).

In the Black Sea, the zooplankton density is relatively high. Bogdanov (personal communication) gives 110,000 tons dry weight of zooplankton for the whole area.

3.3 Benthos

In general, the standing crop of benthos in the Mediterranean Sea is low. Some data on its distribution has been given by Vatova (1949), Pérès (1961), Gilat (1964) and Scaccini (1967). Kiselava and Chukhchin (1965) give values for benthos recorded in some parts of the Mediterranean and the Black Sea; these ranged from 50-300 g/m^2 in the Black Sea off the southern coast of the Crimea, to 0.3-19 g/m^2 in the eastern Mediterranean, 1.5-5 g/m^2 in the Aegean, and 5-8 g/m^2 in the Adriatic. In the Black Sea benthos round the coasts is abundant, but very poor in the oxygen-deficient deep water.

4. FISH STOCKS AND FISHERIES

4.1 The fish

The Mediterranean Sea is far poorer in stocks than most of the Atlantic Ocean and the Black Sea. In general, the catches, both demersal and pelagic, are abundant in species, but of comparatively low quantities.

The fish fauna is basically closely related to the fauna of the sub-tropical Atlantic. The northern part of the Mediterranean Sea includes some species like *Clupea sprattus* and *Nephrops norvegicus* which do not occur in the southeastern part of the Mediterranean. There are about 25 Red Sea species which occur in the eastern Mediterranean but normally do not appear west of Crete. There are also some differences in the availability of commercial species between the northwest and southeast regions. Pilchard, anchovy, bonito and mackerel (*Scomber scombrus*), which are of great commercial importance, occur in the northwest part, while in the southeast they are replaced by *Sardinella*, *Euthynnus*, *Auxis* and Spanish mackerel (*Scomber japonicus*). Hake and red mullets are of great commercial importance for the trawl fishery in both parts of the Mediterranean; however, in the northwest part and especially in deeper water, *Micromesistius poutassou* and *Gadus capelanus*, appear in large quantities. On the other hand, along the coast of UAR, Israel and Anatolia, some of the Red Sea fishes appear in commercial quantities, e.g. *Saurida undosquamis*, *Upeneus moluccensis* and *Sphyraena chrysotaenia* (Ben-Tuvia 1966).

4.2 The fisheries: general

Large industrial scale fisheries are mainly confined to the Black Sea. Elsewhere the general lack of large concentrations of fish has prevented the development of large-scale operations. However, the high price of fresh fish in most Mediterranean countries has favoured the development of a large number of small-scale fisheries. Though the boats concerned are small, and often not highly efficient, their numbers appear to have often been sufficient to fully utilise, or over-exploit, the local stocks, especially of demersal fish. This tendency to over-exploitation is strengthened by the use of very small mesh size in the trawls to retain the smallest individuals among the great variety of species, and also by the not infrequent use of such destructive methods as dynamiting. The fisheries on the major demersal and pelagic species are discussed in detail below. The crustacean and molluscan fisheries, which are also important, are discussed in the relevant chapters.

4.3 Statistics

Because of the small-scale and scattered nature of the fisheries, the statistics are generally poor. Often statistical returns are used for tax purposes and may under-estimate the total catch. Data on species composition, when given, are probably more reliable, but the catch statistics of most countries contain a large proportion of unsorted and unspecified fish.

Effort statistics, except in the forms of number of vessels, are generally lacking.

The statistical data for the Mediterranean, and probably also to a lesser extent for the Black Sea, are therefore unsatisfactory. However, it may be that, given the nature of the fisheries and the magnitude of the potential resource, the considerable effort required to bring the statistics for the Mediterranean as a whole up to the level, say of the Northeast Atlantic, would not be worthwhile.

4.4 Pelagic fisheries

About half the Mediterranean and Black Sea catches are of pelagic species. The sardine (S. pilchardus) constitutes the main catches in the western and north-eastern parts of the Mediterranean. Occasionally it also appears in small numbers in the south-eastern part of the Mediterranean. It is rare in the Black Sea and small commercial catches (10 to 50 tons/year) are reported from the coast of Caucasus. The total yearly catch from the Mediterranean amounts to at least 76,000 tons. Sardinella aurita and S. maderensis occur in commercial quantities in the southern and south-eastern regions of the Mediterranean. The largest catches are taken from the coast of UAR which amount to about 20,000 tons/year. Smaller quantities are taken in the Balearic Islands, Tunisia, Algeria, Sicily, Israel, Lebanon, Syria and southern Greece (Aegean Islands). The total annual catch probably does not exceed 40,000 tons.

The sprat (Clupea sprattus) is taken in some quantities in the most northern parts of the Mediterranean such as the northern Adriatic. It also occurs in commercial quantities in the Black Sea and its annual catch amounts to at least about 10,000 tons (Svetovidov 1964).

Clupeonella delicatula occurs only in the Black Sea and the Azov Sea. It is an euryhaline fish which withstands low salinities.

Anchovy (Engraulis encrasicolus) is important in most of the regions of the Mediterranean and the Black Sea. Catches from the Black Sea are estimated to amount to at least 139,000 tons.

The bluefin tuna (Thunnus thynnus) is caught by a variety of gears. On its migratory routes which include some immigrations from the Atlantic, large traps (madragues) are important. The use of purse-seines is increasing, and hooks and lines and harpoons are also used.

Among the other scombroids, bonito, Sarda sarda, is of the greatest economic importance. It is caught by seines, madragues and hook and line. Auxis and Euthynnus are caught in some numbers, mostly in the warmer regions of the Mediterranean. The mackerels (Scomber scomber and S. japonicus) are caught by purse seiners, with or without the use of artificial lights. Swordfish (Xiphias gladius) is caught in some numbers, particularly in the Sea of Marmara.

Among carangids and related species, several species of horse mackerel (Trachurus) are of commercial importance. They are caught in various quantities by pelagic or demersal gear in practically all the countries of the region. The total catch in the Mediterranean is estimated to be 15,000 tons. The total catch of the Black Sea may reach 20,000 tons.

Other species exploited in various degrees *Caranx fusus*, *Lichia glauca* and *Scyris alexandrinus*. *Seriola dumerili* which reaches a size of 1.5 m is common in the Mediterranean. An attempt has been made to cultivate this fish in saline or brackish lagoons.

The dolphin fish (*Coryphaena hippurus*) is of some importance, especially in Malta and the Balearic Islands.

Six species of grey mullets occur in the Mediterranean and the Black Sea. Among them *Mugil cephalus* and *M. ramada* are of considerable economic importance mainly in the estuary fisheries and are caught with special gear adapted to their habit of jumping over the headline of the net. In some areas, for instance in Tunisia, Italy and Crimea, they are cultivated in closed lagoons and lakes.

Sharks are of minor importance. The large species *Carcharias glaucus*, *Lamna cornubica*, *Oxyrhinhus glaucus* and *Carcharodon carcharius* are caught occasionally by hook and lines, and in the madragues. The small demersal *Mustelus* and *Acanthias* are caught mostly by trawl.

4.5 Demersal fisheries

These are mainly carried out by small trawlers, but lines and traps are locally important, especially when the bottom is rough and unsuitable for trawling. A large number of species are taken. Trawl catches include a quantity of pelagic species, e.g. mackerels, as well as crustaceans and cephalopods.

Among the demersal fish, hake (*Merluccius merluccius*) is one of the more important in all the countries bordering the Mediterranean Sea. It is usually caught in deeper waters but seasonally, particularly in winter, occurs also in shallow coastal waters.

In the western and northern parts of the Mediterranean, *Micromesistius poutassou* and *Gadus capelanus* are caught by trawl. These fish do not occur in the Levant. *Phycis blennioides* appears also in deeper waters and it seems that in some regions is under-exploited. Many sparids, triglids, scorpaenids and mullids appear regularly in the trawl catches.

4.6 Stock assessment: Mediterranean

Few quantitative studies have been made of the state of the stocks, and of the effect of fishery on them. The best studied areas are off Spain, in the northern Adriatic.

Some trawling grounds seem to be grossly over-exploited. It was found by Larrañeta and Suau (1965) that the effort applied in Castellón, eastern Spain, was 3 to 4 times higher than the calculated optimum. By drastic reduction of the effort and increase of mesh size, catches four times higher are expected, and similar situations might also exist in some heavily exploited trawling grounds around Italy and Greece.

Similarly in the Adriatic Zupanovic (1968) has shown a severe effect of fishing on the stocks of hake, and emphasised the need to regulate the demersal fisheries in the area (Zupanovic 1964). However, he showed that these were local differences in fishing intensity, which were reflected in differences in size composition. There may, therefore, be local stocks which are still under-exploited, and in better distribution of fishing would give an increase in total yield. The effects of heavy fishing in the Adriatic have been shown for sole by Piccinetti (1967). In the north-western part the catch per unit effort fell by half between 1962 and 1965 at the same time as the effort increased rapidly.

The degree of exploitation in other areas may be gauged from the data in Table C2. This gives the total catch by each country, the demersal catch (estimated as the main demersal groups plus two-thirds of the unsorted and unspecified fish), the extent of the shelf area off each country, and the estimated catch per unit area.

Table C2 - The area of the continental shelf in the Mediterranean[1] related to the marine catch of each country. Catches represent averages for 1963-5

Country	km²	Catch ('000 tons)		Yield (tons/km²)	
		Total	Demersal	Total	Demersal
Albania	5,450	3	Unknown	0.6	?
Algeria	10,700	19	3	1.8	0.3
Cyprus	2,500	ø	Unknown	0.4	?
France	20,450	21	5	1.0	0.3
Greece	57,000	87	36	1.5	0.6
Israel	3,250	4	1	1.2	0.3
Italy	120,740	252	75	2.1	0.6
Lebanon	1,450	2	1	1.4	0.7
Libya	55,000	2	Unknown	0.04	?
Malta	5,460	1	1	0.2	0.2
Morocco	4,480	6	Unknown	1.3	?
Spain	44,100	116	37	2.6	0.8
Syria	1,160	1	Unknown	0.9	?
Tunisia	77,300	23	6	0.3	0.1
Turkey (Mediterranean coast)	26,100	10	Unknown	0.4	?
Yugoslavia	43,500	24	4	0.6	0.1
UAR (Egypt)	29,200	30	7	1.0	0.2
TOTAL	511,140	591	175+	1.2	

Notes - [1] Down to 100 fm (180 m). Calculations based on the British Admiralty Charts, Mediterranean Sea - Western Sheet 2158 A and Eastern Sheet 2158 B

ø Less than 1,000 tons

This table, and especially the last columns, should be treated with some caution. In addition to some doubts about the accuracy of some statistical information, not all the catches by some countries are taken off the coasts of that country. Spanish statistics include landings in Mediterranean ports of fish caught outside the Mediterranean; and Spanish, Italian and Greek catches include fish caught along the North African coast. Thus the figures over-estimate the yield from the waters off Spain, Italy and Greece, and under-estimate the yield from some North African waters.

With these reservations, there is a fair degree of consistency in the real yields per unit area - around 1-1.5 tons/km² (10-15 kg/ha) of all fish, and some 5 kg/ha for demersal fish. The only area where the yield seems very low is off Libya. No good data are available on the resources of the area, but if they were the same as other areas, additional catches of 50-75,000 tons (ca 25,000 demersal species) appear likely.

Moderate expansion also seems likely along other parts of the north African coast. Thus, Rafail *et al.* (1969) show that there are unexploited stocks off western Egypt; the FAO/USSR stu tour on R.V. AKADEMIK KNIPOVICH (Anon. 1969) surveyed some of the resources off eastern Tunisia.

In the rest of the Mediterranean, by analogy with the few well-studied areas, it is likely that the demersal stocks are in general fully exploited. Some small increase, perhaps 10-30%, could be achieved by a more rational pattern of fishing. This would involve both less fishing, and protection of the smaller fish, in many areas, and increased fishing on certain local stocks still under-exploited. This would give increases of 20-50,000 tons.

At present, demersal fishing is limited mainly to the upper part of the shelf, mostly in less than 100-200 m depths. Recently more interest has been paid to the possibilities of greater exploitation of the upper part of the continental slope, i.e. down to ca 500 m. Present knowledge has been summarised in a report by a working group of the General Fisheries Council of the Mediterranean (GFCM 1969). Summary data are also given for the eastern Mediterranean by Ben-Yami (1969).

This shows that catches of commercial species can be made in depths down at least 500 m. A variety of gears have been tested - lines and traps as well as trawls, since the very rough ground makes trawling very difficult in some areas. Fishing with high-opening trawls in the upper part of the slope has given good catches of pelagic species (e.g. mackerel), where the standard trawl, catching only truly demersal species, took very little.

In some areas, deep water fishing has already started on a commercial scale; in others the catches are very small, e.g. 5 kg/hour off north-eastern Spain, so that the immediate possibilities of commercial exploitations are slight. Altogether, it seems that opportunities exist for increasing catches by fishing the deeper water, but that the increases in total catch are unlikely to be very great, perhaps a further 10-20%.

The degree of exploitation of the pelagic resources is less well-known. The bluefin tuna appears to be heavily exploited, though precise assessment is difficult owing to the scattered nature of the fisheries, and uncertainty concerning the relationships between different groups of fish (FAO 1968). Most Mediterranean catches are of large mature fish, and therefore vulnerable to the development of fisheries in the youngest stages. No great expansion of catch seems likely.

Catches of other pelagic species could probably be increased by further developing the present fisheries for sardinella, small scombroids, carangids and mugilids, particularly along the coast of North Africa, Anatolia and eastern Adriatic. Protection of young sardines in heavily exploited areas might prove beneficial (Larrañeta and Suau 1966). This could be done by implementation of laws on the minimum size limits, by mesh size regulations and other protective measures, but additional studies are needed. There is a need for better evaluation of the available resources. At this stage of our knowledge of the resources, it is difficult to be precise in evaluating the potential catch. It might be 20-50% higher than the present catch, but it seems unlikely that the resources could support the large industrial catches of the scale of those in more productive areas.

4.7 Stock assessment: Black Sea

A review of the potential of the Black Sea, including the Sea of Asov, is given by Moiseev (1969); this study also compares the production and consumption of phytoplankton, zooplankton, benthos and fish. He estimated the production of fish as 1.0 million tons (0.8 million in the Sea of Asov), and the catch of 0.38 million tons (0.3 million from the Sea of Asov). The catches given for the Black Sea (excluding the Sea of Asov) - 69-110,000 tons in 1960-5 - seem low, (see Appendix Table C1), since the Turkish catch above (60-80% of which comes from the Black Sea) approaches this level.

It seems that the Black Sea and Sea of Asov could yield somewhat higher catches, up to perhaps 50% of the estimated production, or slightly more, i.e. 0.5-0.6 million tons. There is indication that fisheries for anchovy, spratt and horse mackerel could be intensified. Some of the coastal areas, if more fully exploited by trawl, could yield increased catches of whiting, spiny dogfish and squids.

5. DISCUSSION AND SUMMARY

With the exception of the Sea of Asov, which can be considered a vast shallow fish pond with fish catches of around 8 tons/km^2, the region is characterised by low production at all stages. Some increase in present catches is possible, with better management of the presently over-exploited stocks, and exploitation of some of the deep water and other resources for which catch rates may at present reach a commercially attractive level, this increase might be as much as 50%, i.e. a total catch from the Mediterranean and Black Sea of around 1.5 million tons.

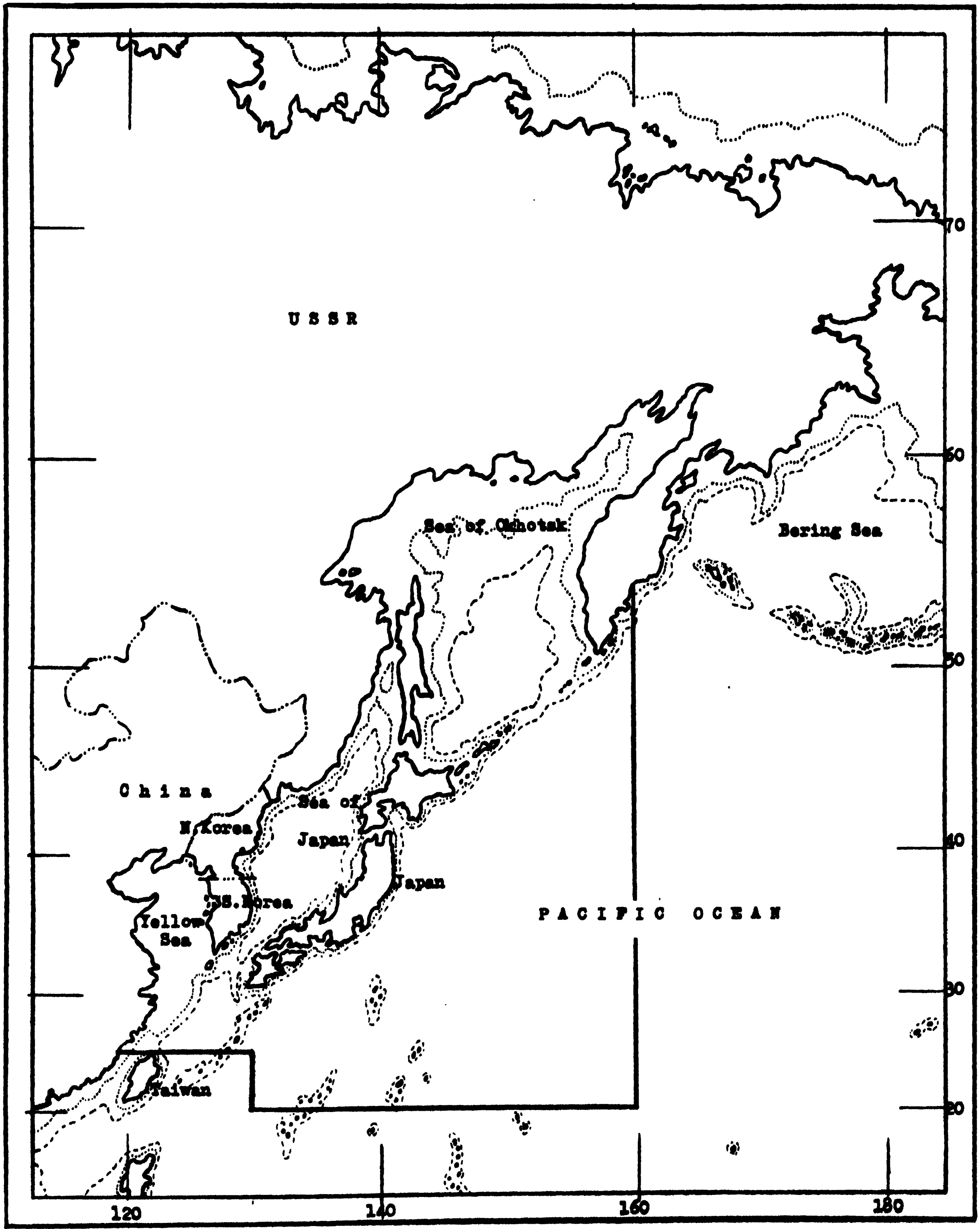
5.1 Future studies

The estimates obtained here are in most cases rough, though probably as good as could be obtained with the presently available data. Much could be done to improve the estimates, but the following appear to be the more important:

(a) Better statistics. Present statistics seem inadequate in many ways; total catch is probably not very accurate for many inshore fisheries; species identification is often poor; and effort data is generally lacking. Work towards improved statistics is being undertaken by a working party of the General Fisheries Council for the Mediterranean.

(b) Assessments of exploited stocks. The assessments already made of a very limited number of stocks should be extended to other stocks, and especially to the study of the multi-species fisheries in which small species, and large numbers of small individuals of larger species are taken together.

(c) Quantitative surveys of lightly exploited stocks. These probably include demersal fish off parts of North Africa, and several pelagic stocks. Methods could include trawling and acoustic methods.



D - NORTHWEST PACIFIC Depth contours at 200 and 2,000 m

INTRODUCTION

The Northwest Pacific as defined here is broadly delineated as north of the Western Central Pacific excluding the Bering Sea. The review for the Western Central Pacific defines its northern boundary from 35°N to 145°E and thence at 40°N to 180°. However, as it does not include all living resources around southern Japan, these will be considered here as far as relevant.

The fishing grounds for saury and skipjack extend eastward over 145°E long. and the offshore salmon fisheries also operate across the Aleutian Chain in the western Bering Sea. These resources, and the whale stocks in the North Pacific are presently difficult to discuss regionally, and will be reviewed here generally. No attempt will be made to review the fur seal resources for which commercial sealing at sea is prohibited, as is the exploitation of other marine animals, under the North Pacific Fur Seal Treaty.

The Northwest Pacific is, or rather includes, one of the most intensively exploited fishery regions of the world, comparable, on the one hand, with the North Sea, and to the Northwest Atlantic on the other. One of the features is a great variety of fishery resources for commercial use, and the other is a predominance of pelagic resources over bottom living animals, excluding molluscs and algae in the littoral zone. These features evidently reflect the natural, presently uncontrollable, conditions - topographical, hydrographical and biological - in the Northwest Pacific; but of equal importance in determining such a characteristic course of fishery exploitation, along the coasts concerned, has been the demand.

1. BOTTOM TOPOGRAPHY

Two arcs of the islands, the Kuril and the Japanese, and two peninsulas, Kamchatka and Korea, cut off two basins from the Northwest Pacific Ocean - the Seas of Japan and of Okhotsk. The Sea of Japan is separated from the adjacent seas by shallow straits (not deeper than 130 m), while the straits connecting the Sea of Okhotsk with the Pacific are deep, though they fall short of the greatest depths of the sea.

The Sea of Japan has a small shelf and the abyssal zone is rather predominant in its bottom topography. The area is about 978,000 km^2 and the average depth about 1,750 m. Its greatest depths (about 4,000 m) are found in the northern abyssal zone. The shelf is very narrow except for Peter the Great Bay, the northern part of Tartary Strait, northwest offshore of Hokkaido and in the vicinity of Korea Strait. It occupies only 20% of the total area, and the bathyal and the abyssal zones about 40% respectively. In the southeastern part of the sea lies a large submarine range, with some of its elevations rising to within 300 to 400 m of sea level. Moreover, here and there in the trench some summits rise to a height of 1,500 to 2,000 m from the sea floor.

The Sea of Okhotsk, on the other hand, has a fairly limited abyssal zone in the south and its bathyal zone is greatly developed. The area is about 1.59 million and the depth is about 860 m on the average with a maximum of about 3,660 m. The deep trench in the south stretches in a latitudinal direction, south of 48°N, demarcated from the north by the 3,000 m isobath. The central part of the sea is 1,000 to 1,500 m deep forming some terraced elevations. The 1,000 m isobath cuts across the central hollow of the sea from the southeast corner, and the northern ledge at a depth of about 200 m borders the northern shallows (the shelf proper) on its southern side. The shelf zone extends along the coasts of Sakhalin, Okhotsk District and West Kamchatka.

Outside the Kuril Islands lies one of the deepest trenches in the world - the Kuril-Kamchatka Trench, running to the southwest along the Islands from offshore of Southeast Kamchatka. Turning to the south along the northern coast of Japan, the Trench, now called Japan Trench, extends on into the tropical region towards Mariana Trench. These trenches, with their maximum depths of about 10,000 m, are very narrow and to the east lies a vast oceanic plateau about 5,000 m deep. To the west of southern Japan Trench runs southward a submarine range, South Honshu Ridge, with many volcanic summits above water. Farther westwards, and south of Kyushu, extends another submarine range due southward, and between these ranges lies a basin of about 4,000 m in depth, open southward to the Philippine Basin. The shelf and the bathyal zones are both quite narrow east and south of these two arcs of the islands.

Table D1 - The areas of the shelf by region

Region	Area ('000 km^2)	
Sea of Okhotsk	580 (610)**	
Sea of Japan	196 (202)**	
Along West Sakhalin and Asian Mainland		93 (99)**
Along the Japanese Islands		103
Northwest Pacific	134	
Southeast Kamchatka		29
Southern Kurils		24
Northern Japan		53
Southern Japan		28
West Coast of Kyushu*	49	
TOTAL	959 (995)**	

Notes - *East of 128°E and southward from the middle of Korea Strait
**Estimates by Dryugin (Moiseev 1953)

2. HYDROGRAPHY

As in the Northwest Atlantic, cold water masses from the north meet here with warm water masses from the south. Their convergence affects not only the climate of the coastal regions but also the whole biological environment. Generally, it creates favourable conditions for existence of quantatively very rich flora and fauna, and zones of sharp heterogeneity where Arctic boreals and sub-tropicals meet. The bottom topographies described above give some further peculiarities to the Seas of Japan and Okhotsk. The waters, especially the surface 200 m layers, in the surroundings of the Japanese Islands are well covered by many hydrographical observations.

The Kuroshio Current, one of the well-defined sectors of the oceanic circulation in the Pacific, flows eastward just south of southern Japan and, crossing over the South Honshu Ridge, extends nearly due east meandering towards the West Wind Drift in the North Pacific. South of southern Japan it runs with maximum velocities up to 160-180 cm/sec but only within a distance of 140 km from the coast. Out of the limit, at greater distances, a counter-current flows to the southwest, where maximum velocities up to 20 cm/sec are encountered. The volume transport of the Kuroshio above 1,500 m has been estimated about 65 million m^3/sec south of southern Japan (Sverdrup et al. 1942). Recently it has been observed that west of the South Honshu Ridge there sometimes develops a large scale of eddy, accompanying some upwelling, between the coast and the Kuroshio, which greatly changes the flow pattern of the Kuroshio there (Uda 1949, Ichiye 1955, Moriyashu 1955, Shoji 1957, Watanabe 1957, Fukuoka 1958, 1960). The temperatures of the Kuroshio are comparable to those of the Gulf Stream in the North Atlantic (25°-27°C at the surface layer in summer), but the salinities are much lower and at maximum slightly less than 35.00°/oo (about 36.50°/oo for the Gulf Stream). The vertical gradient of temperature is rather indistinct during January to May and the transparency decreases due to a thick concentration of diatoms in the upper layer. During June to November, on the other hand, a density stratification develops with a remarkable discontinuity of temperature and chlorinity around 100 m depth. The transparency then increases (up to about 30 m) and a fraction of incidental light may reach a 100 m depth, possibly supplying enough energy for diatom growth there (Marumo 1957). Needless to say, the Kuroshio Current is never in a steady state (Ichiye 1955). The volume transports calculated for the cross section south of southern Japan indicate that it varies over a two-fold range within a year. Variable as it is, it appears to increase twice a year, in spring and in autumn (Masuzawa 1958).

The Kuroshio Extension, over the South Honshu Ridge, becomes rapidly mixed with the cold water of the Oyashio that flows south close to the northeastern coasts of Japan, sinking down under the Kuroshio. Along the boundary numerous eddies develop, where a thorough mixing takes place (Hikosaka and Watanabe 1957). Through these processes of horizontal mixing, coupled with cooling in winter and precipitation over evaporation, a water mass, called the Subarctic Water, is formed and prevails in the North Pacific. Recent studies have confirmed that, in addition to the counter-clockwise gyres in the Bering Sea and in the Sea of Okhotsk, there exists another gyre of Subarctic Water south of Southeast Kamchatka and the western Aleutian Islands (Hirano 1957, 1958, 1961, Dodimead et al. 1963). Along these gyres, the cold water masses, further cooled in the Bering Sea or in the Sea of Okhotsk, outflow southward along the east coast of Kamchatka or through the central or southern Kurils towards offshore of north Japan as the Oyashio. The volume transport above 1,500 m for the cross section off the northern Kurils has been estimated as about 15 million m^3/sec, one-third of which comes from the Okhotsk Sea and another one-third from the Bering Sea (Sugiura 1958). One of the permanent features of the Oyashio is a halocline found in the depth interval about 100 m to 200 m. In the upper zone a marked thermocline develops during summer and vertical mixing proceeds deeper from the surface during the cooling season. Such a seasonal process, however, generally stops at the depths of the permanent halocline (Dodimead *et al*. 1963). Another feature of the Oyashio is a temperature minimum, accompanied by the halocline and originated from the areas of sea ice formation, primarily from the Sea of Okhotsk (Kajiura 1949, Uda 1963). The temperature of this layer in the Sea of Okhotsk is between -1.8°C and 1.0°C, but it becomes warmer southward because of mixing along its path. Because of precipitation over evaporation (generally found north of 45°N in the North Pacific), the salinities in the upper layer are around 33.00°/oo. The transparency in the Oyashio (about 13-19 m in summer) is much less than in the Kuroshio.

A branch of the Kuroshio flows into the Sea of Japan through Korea Strait and carries water of high temperature and high salinity to the north mainly along the coast of Japan. Because of shallowness of the straits, however, all the deep waters are isolated from the trenches of the Pacific Ocean and other adjacent seas. The surface currents have a cyclonic, counter-clockwise character, and there appears to exist a hydrographical contrast between the waters along the coast of Japan and those along the coasts of Primor'e and Korea Peninsula. Generally true as it is, a comparison with the Northwest Pacific indicates homogeneity rather than contrast as one of the features (Fukuoka 1962). The surface salinities in the northern Sea of Japan are about 33.60°/oo, a little higher than in the Oyashio, while those of Tsushima Current flowing into the Sea of Japan are fairly lower than in the Kuroshio Main. That is, the difference is not so sharp between the waters in the north and south as in the Northwest Pacific. Almost the same is observed on temperature and dissolved oxygen. The vertical distribution of density in summer in the northern Sea of Japan is similar to that in the Oyashio, but they clearly differ from each other in winter; the density in the Sea of Japan is vertically almost homogeneous, while more or less stable density stratification is maintained throughout the year in the Oyashio and in the Sea of Okhotsk. The temperature of the northwestern part of the sea falls sharply in winter and the Tartary Strait is covered with ice from November to April. As a result os sinking of cooled surface waters along the slopes, the deep waters are well aerated and characterised by their lower temperatures and by the absence of oxygen deficiency (Zenkevich 1963). Recent analysis indicates the ascending motion may appear in the central part of the sea (Fukuoka 1965). In the southeastern part as well, intensive vertical mixing in winter is also observed (Koshimizu 1958). Another feature is found in the seasonal variation of Tsushima Current. The volume transport calculated for the cross section east of Korea Strait shows a maximum of 2.2 million m^3/sec in September and a minimum of 0.23 million m^3/sec in March. That only one maximum is observed in a year is confirmed for the other sections in the Sea of Japan, noteworthy in contrast with possibly two maxima in the Kuroshio (Miyasaki 1952, Hata 1962).

In the Sea of Okhotsk the climate is more severe than in the Sea of Japan and the sea is almost entirely covered with floating ice in winter. Even early May the northern half of the sea (excluding narrow shore belts) is still under floating ice. Vertical mixing does occur in winter, but the permanent haline structure, prevailing in the North Pacific, confines it within the upper 50-100 m layer and the cold intermediate layer develops throughout the year. The surface currents, generally weak, appear to depend on winds, but analysis of the cold intermediate layer discloses a general counter-clockwise circulation. As previously suggested, oceanic waters penetrate freely into the sea through the deep straits in the northern Kurils so much as balancing the outflows towards the Oyashio (Kajiura 1949, Sugiura 1958).

3. PLANKTON

Many plankton studies have been reported, but most of them seem to be limited in scope to particular localities and/or particular species, and to be more or less qualitative in nature. The general features of their distribution in the Northwest Pacific have been well summarised in some of them (Shimomura 1957, Bogorov 1958, Motoda and Marumo 1963, Zenkevich 1963, Ohwada and Ogawa 1966, Marumo 1967). In the last ten years measurements of chlorophyl contents and of primary productivity by radioactive carbon tracer have been much advanced, although still far from satisfactory there is coverage of the region concerned.

3.1 Phytoplankton and primary production

Generally, in the Oyashio region, along the Kuril Islands and offshore to the east of northern Japan, the phytoplankton populations are composed of boreal diatoms, while in the Kuroshio region of typically warm water species. In the mixing zone between them, the population is represented by some cosmoplitan species such as continuously distributed eastward across the ocean. The phytoplankton between the southern coasts of Japan and the Kuroshio is strongly neritic in nature. It is interesting to note that along the convergence of the Kuroshio and the Oyashio some neritic diatoms are predominantly distributed offshore even as far as 155°E.

Two ocean weather stations provide valuable information on the seasonal cycle of the phytoplankton in the high sea region (Kitou and Asaoka 1956). At the point X 39°N, 153°E), alternately under the influence of the Oyashio or the Kuroshio water according to season, a bimodal cycle of production is observed with peaks in spring and autumn. At the point T(29°N, 135°E) in the area of the Kuroshio water, the phytoplankton develops in late winter through spring. Their seasonal cycles along the coasts are greatly variable with localities. In the Kuroshio water south of Japan, the greatest crop of diatoms is found in the upper 25 m layer during January through May. Their higher concentration during June to November, on the other hand, is separated into two layers, that is in the upper 10 m and about 100 m depths, probably because of stable stratification.

A recent cooperative survey (1962-3) has found the standing crop of phytoplankton along the coasts of Japan to be in the order of 10^5 to 10^6 cells/l, much higher than the 10^3 to 10^4 cells/l observed in the comparable survey in 1930-3, although no explanation can be found as yet. In the Oyashio region it is generally as high as 10^4 to 10^6 cells/l, while in the main flow of the Kuroshio it is usually about 10^2 to 10^3 cells/l, and to the south extends a vast region where the crop is less than 10^2 cells/l. In the neritic waters along the west and south coasts of Japan and also in the Mixing region east offshore it is usually in the order of 10^3 to 10^4 cells/l.

The same appears generally true in the Sea of Japan. The standing crop in the northern part of the sea reaches 10^5 to 10^6 cells/l, comparable to the crop in the Oyashio region (Zenkevich 1963). Recent observations, however, indicate homogeneity rather than contrast, as also applies to the hydrography. In the central Sea of Japan the standing crop in winter (January to March) is observed to be about 10^4 cells/l, decreasing northward and to the southeast, while in summer (July to September) it is less than 50 cells/l, increasing towards the coasts, especially to the northeastern part of the sea (Ohwada and Ogawa 1966, Kawarada et al. 1966). Some Arctic and Arctic-boreal species are predominant in northern Sea of Okhotsk during the spring-summer bloom and only a single bloom per year is recorded owing to the severe climatic conditions. The crop, however, may reach 20 mg/m^3 with 7×10^6 cells/l (Zenkevich 1963). In the southern Sea of Okhotsk the crop is observed to be less than 10^2 cells/l, except for the coastal waters near La Perouse Strait (Kawarada et al. 1966).

In chlorophyll content also there exists a clear difference between the Kuroshio and Oyashio regions. Slightly varying calculations have been made by authors but the following averages can be given: surface chlorophyll contents in summer averages 0.5 - 0.7 mg/m^3 for the Oyashio, 0.1 - 0.3 mg/m^3 for the Kuroshio, and 0.3 - 0.5 mg/m^3 for the mixing zone. It is higher towards the south coast of Japan, but this tendency is not so marked off northern Japan (Saijo and Ichimura 1960, Aruga and Monsi 1962, Ichimura 1965). In the Kuroshio chlorophyll is rather evenly distributed in the upper layer of the euphotic zone, followed by a slight increase with increasing depth. In the Oyashio and in the Littoral region of the Kuroshio, the maximum chlorophyll content occurs not at the surface layer but at the depth where the light intensity reduces to about 10% or less of the surface intensity. Maximum daily productivity on a clear day is found at about 20 m depth in the Kuroshio and at about 5 m depth in the Oyashio. The gross production for the entire euphotic zone per m^2 sea surface is estimated as 0.36 gC/day in the Kuroshio, and 0.83 gC/day in the Oyashio on a clear day. On a slightly clouded day it reduces respectively to 80-86% or 46-58% of the value of a clear day (Aruga and Monsi 1962). Along the southeastern Kamchatka and east offshore of Hokkaido the daily gross production is observed to be higher than 0.65 gC (Koblenz-Mischke 1965, Kawamura 1963), but farther offshore in the Western Subarctic Gyre it is observed to reduce to about one-third of this (Kawamura 1963). Upon analysis of oxygen and phosphate budgets under some hydrographical assumptions, it is independently estimated that the average daily production is 0.22 gC at the outskirts of the Gyre (Sugiura and Yoshimura 1964).

In comparison with the N/P ratio of the phytoplankton cell (16), the N/P ratio of sea water in the Northwest Pacific under consideration, after filtration of plankton, is observed to the strikingly low, ranging from 0 to 2.6 in the euphotic zone, especially in the Kuroshio (0 - 1.9). Very low as it is, phosphate is present in the euphotic zone with a sharp difference between the Kuroshio (almost less than 1 mg/m^3) and the Oyashio (6-69 mg/m^3), but nitrate and nitrite seem to be entirely exhausted, especially in the Kuroshio.

In the Sea of Japan, before the spring bloom, the daily gross production is 2-6 mgC/m^2 during the greatest bloom, when it is 50-115 mgC/m^2 in the eastern part of the sea. The highest production (5 gC/m^2/day) was recorded east of Hokkaido within the zone of convergence of warm and cold water masses. South of 40°N it hardly rises above 100 to 150 mgC/m^2/day (Sorokin and Koblentz-Mishke 1958).

3.2

The distribution of boreal copepods is limited to the north of the Kuroshio Extension. Tropical or sub-tropical copepods are generally distributed in the south of the Kuroshio. Their distribution hardly changes by season, but the northward distribution of warm water species beyond the Kuroshio is more frequently observed in winter. In the Kuroshio region copepods are most abundant at about 40 m depth in the daytime. The majority of the zooplankton is observed to be present in the 0-100 m depth. The biomass (wet weight) in the upper 100 m is usually less than 50 mg/m^3 on the oceanic side of the Kuroshio, while more than 100 mg/m^3 on the neritic side. In the Oyashio region it is generally small in winter and less than 50 mg/m^3 except for biomasses larger than 100 mg/m^3 occasionally observed southeast off Hokkaido. In summer, however, there is a remarkable increase up to 250-500 mg/m^3, especially east of Hokkaido. In the Kuroshio region, on the other hand, there is no distinct seasonal change in the zooplankton biomass observed (Motoda and Marumo 1963). Zenkevich (1963) has schematically shown a distribution of plankton biomass for the cross-section over the Kuril-Kamchatka Trench. From the neritic to the oceanic zone it generally decreases from 400 mg/m^3 to 30 mg/m^3 with a slight increase to 500 mg/m^3 towards the zone of convergence of the cold and warm water masses. The qualitative variety of plankton increases with depth, but its biomass decreases sharply to about one-tenth of the surface biomass at the depth of 200-500 m.

It should be noted here that, because of sampling techniques, fish larvae are not always well represented in the above estimates of biomass. The spawning grounds of some commercially important fish, such as jack mackerel, common mackerel, yellowtail, common squid, and so on, are located southwest of Kyushu, and the Kuroshio or Tsushima Currents usually play an important role in transporting these resources along both coasts of Japan (Hattori 1964, 1965).

The northern part of the Sea of Japan is occupied by cold water species while the warm water species inhabit the southeastern part of the sea. They are much more developed in the open sea, furnishing a biomass in excess of 1,000 mg/m^3. In winter (December to February) their biomass in the upper 200 m remains fairly well developed in the central part (30 to 500 mg/m^3). Zooplankton distribution in the north has some unusual winter features. The highest concentration may be found in the upper 25 m layer. The biomass rapidly decreases within the 100 to 200 m layer and then deeper down it becomes considerably richer (a little less than 200 mg/m^3) before it decreases again. Many of the plankton species sink down in the Sea of Japan to much greater depths than usual for them in the Pacific. Qualitatively and quantitatively, however, the deep water fauna in the Sea of Japan is considerably impoverished and it is noted that a large number of plankton species found in the upper layer of the adjacent seas do not penetrate into the sea (Zenkevich 1963). The biomass in summer is about 100 mg/m^3 in the central Sea of Japan, more or less increasing towards the northwest, while decreasing to the southeast to about 25 mg off the west coast of Japan (Kawarada *et al.* 1966).

In the north of the Sea of Okhotsk cold water organisms are predominant in the summer zooplankton. The greatest biomass (1,000 to 3,000 mg/m^3) was once recorded in the northeastern part at depths of more than 25 m at some distance (100 to 150m) from the coast. The vertical distribution of Okhotsk plankton is greatly affected by the presence of the cold intermediate layer. Generally the biomass decreases markedly at depths of 40 to 50 m, increasing again below the cold layer at 100 to 150 m. The number of species in the deeper layer is much increased and some of them do not penetrate at all into the upper layers (Zenkevich 1963).

In the south of the Sea of Okhotsk the zooplankton biomass in summer ranges from 86 to 302 mg/m^3 with an average of 180 mg/m^3. It is usually low in the offshore waters, but the second largest biomass on the average is observed there within the regions under consideration (Kawarada *et al.* 1966).

4. BENTHOS

Probably because of difficulties of quantitatively reliable sampling, studies on geographical distribution of benthos seem to have been descriptive in nature except for those regarding particular bays or inlets and on commercially important species (Aikawa 1934, Horikoshi 1962, Zenkevich 1955, 1963). In this respect the Sea of Okhotsk appears to be the best surveyed in the Northwest Pacific.

The coastal flora of the Sea of Okhotsk comprises about 162 species of seaweeds. The Kuril Island flora is considerably richer, because of penetration of a series of oceanic and mainly warm water forms. The tidal range is no more than 50 cm on the southern coast of Sakhalin through the Kurils, while it attains more than 13 m in the Penshinskya Inlet. A rich littoral population is concentrated in those coastal sectors, protected from the swell, in the inlets and bays of the northern coast. The bottom animals are classified according to their manner of feeding into such ecological groups as mobile and sessile sestonophages, mobile and sessile detritus-feeders, carnivores and carrion-eaters (Savilov 1957). Their distribution in space discloses the ecological structure of the bottom-living fauna throughout the sea. Horizontally it looks quite irregular as a result of complex bottom topography, variety of bottom soil, complicated system of water circulation and changes in temperature. A certain vertical zonation, however, is observed in the distribution. Rock soils in the coastal areas are commonly predominantly occupied by a fouling fauna. With increase in depth it is replaced by mobile sestonophage. Adjacent to it extends a wide zone with a predominance of detritus-collecting forms; Mollusca are replaced by Ophiura, and finally in the lower horizons of the zone the Polychaeta, as the most eurybiotic forms, acquire a dominant role. The group of bottom-feeders or sessile sestonophages of soft soils becomes intensely developed in the central deep water, on diatomaceous oozes rich in plant food. The densest benthos colonies, with a predominance of fouling fauna, are found off the northern and the eastern shores of the sea, where the total biomass is frequently of the order of 1 kg/m^2. In the deep trench in the central part the benthos biomass is extremely small, as low as 10 mg/m^2. In the total benthos biomass (about 300 million tons), Mollusca occupy the first place (about 30%); Echinodermata come second (about 25%) and the Polychaeta third (about 12%). Benthic biomass on the continental shelf are well summarized by Moiseev (1953, 1955). The largest biomass per square metre is found off West Kamchatka in the southern and the northern part (more than 650 g/m^2 on the average). It decreases towards the northeast corner of the sea to 50 g/m^2 and then increases southward to the second largest biomass in Taraika Bay (about 540 g/m^2). In the southern part off West Kamchatka and off South Sakhalin more than half of the benthic biomass is qualified for food organisms.

Three hundred and seventy-nine species of bottom-living macrophytes are listed in the Sea of Japan. Along the coast of Primor'e Arctic-boreal species are predominant in the northern part and boreal ones in the southern. Most of them are endemic to the northern part of the Pacific and some are amphi-boreal. Vast fields of the commercially utilized marine grass Phyllospadix occur at 0.5 to 15 m depth in some areas of southern Primor'e. Bottom fauna has been well studied for the Peter the Great Bay area, where life is much more abundant on soft soils in the littoral than on the rocky littoral. In the sublittoral zone, fields of the sea grass Zostera give shelter to abundant fauna. Somewhat below them in the Horizon of Laminaria and red algae, the Polychaeta make up half of the biomass and the second and third places are occupied by Echinodermata and Mollusca on a sandy silt soil, while Crustacea are predominant (70 to 95% of the biomass) on purer sand. At greater depths (80 to 200 m) the total biomass becomes noticeably less and farther down is considerably impoverished. It is a feature of the Sea of Japan, in comparison with the neighbouring Sea of Okhotsk, that the bottom fauna becomes markedly poorer in species composition with increas ing depth. In the Sea of Japan also, the biomass itself decreases noticeably as depth increases (Zenkevich 1963). The biomass on the shelf along the Asian mainland is generally low (94-340 g/m^2) and the greatest biomass is found in Peter the Great Bay at the depths 50-80 m along the coast of Primor'e (Moiseev 1953).

In the surroundings of the Japanese Islands the bottom flora comprises 864 species, of which 310 species are endemic to the region. To the north of southern Hokkaido are distributed Arctic-boreal or boreal species. Along the southern coasts of Japan through west of Kyushu prevail subtropical forms. Generally chlorophycea species increase in number to the south Phaephyceae (Uyeda _et al._ 1963). Bottom fauna is here again very variable, depending on variable local conditions. Broadly speaking, Porifera and Coeleterata are abundant along the southern coasts of Japan through west Kyushu into Korea Strait and again towards Tsugaru Strait. Annelida are widely distributed with a predominance of Sedentaria. Crustacea, mostly Decapoda, are also widely distributed but usually as a member of biocoenosis there. Among Echinodermata, Asteroidea, Echioidea, and Holothuroidea are dominant on sandy beds along the Pacific coasts. Warm water Ophiuroidea, found in muddy regions on the Pacific region also, are more abundantly distributed farther offshore on the Sea of Japan side. Mollusca are rather more abundant and distributed towards offshore in the southern part of the Sea of Japan. The eutrophic region lies west of Kyushu into Korea Strait and extends over the shelf of the southern Sea of Japan. Towards Tsugaru Strait again is observed a narrow but eutrophic region (Aikawa 1934).

In Japan many species of these bottom flora and fauna have long been utilised for human food and raw materials of agar, algin, gelose and carrageenin, some of them being commercially cultured. Consequently, biological studies on them are greatly advanced, but problems of culture are left out of the present review.

5. FISHERIES AND THEIR RESOURCES

About 2,500 species are listed in the 'Key to the Fishes and Fishlike Animals of Japan' by Okada and Matsubara (1938). Probably a good many of the species may be duplicated, but Rass has recently reported about 300 species and subspecies for the Sea of Okhotsk and about 615 species for the Sea of Japan (Zenkevich 1963). The shelf zone is poorly developed in the Northwest Pacific under consideration and consequently there seems to be a considerable predominance of pelagic fishes over bottom-living animals, as compared with, for instance, the Barents Sea. The faunas in the northern part have much in common with those in the northern part of the Atlantic in their amphiboreal characteristics, but many species of fish and invertebrates, in spite of no essential taxonomic differences, vary greatly in their ecology and mass development (Moiseev 1953, 1955).

Commercially about 20 species of fish in the Sea of Okhotsk and about 40 species in the Sea of Japan are utilized by the fishermen of USSR. Hundreds of species, on the other hand, are fished by the Japanese, of which commercial landings are grouped into 66 categories of fishes and 22 categories of invertebrates in the Government statistics. Not only many species of fish, but various kinds of invertebrates, molluscs and crustaceans, and also sea-urchins, sea-cucumbers and ascidians - if edible - are commercially utilised in Japan. Another feature of the Japanese coastal fisheries is that most of the resources have been exploited by several kinds of fishing gears. That is, in general, the Japanese coastal gears are not intended for a particular species, although some species may be exploited in a particular season and with a particular gear. The same appears to be true along the Korean coasts. This fact partly reflects a hydrographical and biological variability in nature found in the Northwest Pacific, but more essentially that there exists a considerable difference in historical, social and economical backgrounds of the respective fisheries.

The USSR fisheries in the Far East had long been confined to the very coastal regions, mainly for herring and salmon. Since the early 1950s, however, the Far East fisheries have begun to be rapidly reinforced by fleets of ultramodern fishing, processing and support vessels, with offshore fishing exclusively encouraged. Along with such large capital investment, about 600 national corporations for processing on land, so far dispersed along the coasts, have begun to be reorganized into fewer and larger units to meet this essential transformation in the fishery. In Japan too, such industrialisation has been promoted since the early 1950s, especially development of high sea fisheries in distant waters by private enterprises and companies under government license controlling their areas and types of operation. In Japan, however, long-cherished demands are distributed all over the country along the coasts and they have kept on supporting the coastal fisheries. There seems, however, to be no such demand distribution along the coasts of USSR.

5.1 Fishery statistics

Fishery statistics for Japan, and recently for South Korea, are well documented but with some difficulties for the present purpose. In some cases they are not always compiled by fishing area. Unfortunately, catch statistics for North Korea and USSR are incomplete. The available statistics have therefore been given in two sets of tables. Appendix Tables D1 and D2 give the total catch in the North Pacific for 1964 to 1968, by country and by major species. The more detailed breakdown by area in the western Pacific (Sea of Japan, Sea of Okhotsk, and the open Pacific, east of Japan and the Kurils). These are given, by country, for the last year (1964) for which complete data are available, in Appendix Tables D3, D4, and D5.

(a) USSR fishery in the Far East

The Soviet Union fisheries in the Far East saw a major transformation during the early 1950s. Since 1955 the total catch has continuously increased - 0.64 million tons in 1955, 0.82 in 1958, 1.55 in 1963 and 1.75 in 1964. In 1958 the southeastern Bering Sea and the Gulf of Alaska began to be exploited by the Soviet fishing fleets. In the mid 1960s about 70% or more of total Russian landings from the North Pacific came from factory-ship operations in those far seas (Jakhonov 1966).

- Herring: The main fishing grounds are northern Sea of Okhotsk and Olyutorsky Bay in Bering Sea. Total catches in the Far East have increased from 136,000 tons in 1955 to 460,000 in 1964. In 1964 65% was landed from northern Sea of Okhotsk and off the west coast of Kamchatka. In nothern Sea of Okhotsk the catch was about 7,500 tons in 1955, increased to 250,000 in 1964 and since then for a few years has been fluctuating between 50,000 and 100,000 thousand tons. There was once one of the most important fishing grounds for herring around Hokkaido, South Sakhalin and Primor'e, where about 18,000 tons of herring was landed in 1964 (Isvestia TINRO 1965).

- Salmon: Salmon catches along the coasts have gradually decreased these last ten years. The catches in thousands of tons of the dominant species are shown for some selected pairs of years[1] as follows:

Table D2 - Salmon catches in the Northwest Pacific

	1955	1956	1959	1960	1963	1964
Chum	65.7	166.6	96.4	73.8	84.1	49.7
Sea of Okhotsk	55.0	66.0	31.3	39.7	26.8	23.0
Sea of Japan	0.1	0.1	-	-	-	-
Pink	88.3	72.4	47.5	19.7	35.7	14.7
Sea of Okhotsk	70.8	53.6	22.6	6.9	18.9	5.3
Sea of Japan	5.0	18.2	11.3	8.0	3.2	2.9
TOTAL	172.4	166.6	96.4	73.8	84.1	49.7

Note - Three other species, sockeye, silver and king, are caught on both sides of Kamchatka Peninsula alone (FAO Statistical Yearbook)

- Gadoids: The catch has steadily increased these ten years, especially of Alaska pollack and navaga. The catch of Alaska pollack was 9,700 tons in 1955, 109,200 in 1960 and 213,600 in 1964. (The USSR catch in 1967 more than doubled that in 1964, but no information is available as to where this was landed. The same is almost true of the Japanese catch, of which the increase comes exclusively from the Bering Sea.) In 1962 82% of the Alaska pollack catch came from Primor'e and 15% from Sakhalin. Navaga was mostly fished around Kamchatka Peninsula, and the catch was 20,000 tons in 1955 and quite recently increased to 30,000 in 1964.

- Flatfishes: The catch increased until 1961, but since then it has decreased to a level of 1956-7. It was 119,200 tons in 1955, 249,600 in 1961 and 141,500 in 1964. In 1962 65% came from eastern Bering Sea, 22% from West Kamchatka and 7% from East Kamchatka. Generally, the catch from the Asian continental shelf has slightly decreased recently. About 5,600 and 7,400 tons were respectively caught in Primor'e and Sakhalin in 1962.

-Rockfish: About 63,000 tons of rockfish were caught in 1962, most of which came from Bering Sea and only 2% from Primor'e. Remarkable increases in 1963 and 1964 (128,000 and 275,700 tons respectively) were exclusively due to the fishing operation in the Gulf of Alaska (Chitwood 1969).

- Other species: King crabs are almost all fished along the west coast of Kamchatka and the catch has been maintained at a level of 30,000 to 35,000 tons in recent years. Pacific saury was caught in the Pacific near the southern Kurils and the catch was 45,000 tons in 1962, 53,000 in 1963 and 27,000 in 1964. About 3,000 to 5,000 tons of seaweeds, mostly kelp, were harvested in Primor'e and Sakhalin (Jakhonov 1966).

The estimated catches in 1964 by area by USSR are summarised in Appendix Table D3.

(b) North Korean fishery

Little information is available. A government release said that the total catch by the Democratic Peoples Republic of Korea amounted to 840,000 tons in 1962 and 640,000 in 1963. Upon pre-war information, at least half of it is guessed to have been landed from the Sea of Japan. A report (Tyan Ir Khan 1962) stated that during 1950 to 1953 a trawl fishery for Alaska pollack had developed. The catch increased to 263,000 tons in East Korea Bay in 1956, almost equal to the highest catch in the past (272,000 tons in 1940). Another report (Kim Sin Syu 1958) indicated that the mackerel catch in the North Korean waters increased to 134,400 tons in 1950, but was reduced to a low level of several thousand tons in 1956-7.

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[1] As pink salmon in odd and even years belong to different populations, although the same grounds may be made use of for spawning, with almost independent reproduction cycles

(c) South Korean fishery

Catch statistics by area are available for 1966. Total catch in 1966 by the Republic of Korea reached 583,200 tons, of which 175,800 tons came from the Sea of Japan side, excluding those districts facing Korea Strait. The catches by species in 1964 from the Sea of Japan side were separately estimated in the 1966 species compositions.

The estimated catches along the east coast of the Korea Peninsula are summarised in Appendix Table D4.

(d) Japanese fishery

As mentioned above, catch statistics in Japan are not always compiled by fishing areas. Such a difficulty appears to increase as the tonnage and powers of fishing vessels increases. Catch statistics by area, given in the Government Statistical Yearbook, were modified according to various information on fishery and resource studies so far as was reasonably possible; however, this was a difficult task and the results are not entirely accurate. The areas at issue are especially Hokkaido and western Japan. Some trawlers on the Pacific side of Hokkaido fish not only in the Sea of Okhotsk but even as far as Bering Sea. Some purse seiners in western Japan go to the East or South China Sea for mackerel or horse mackerel. Effort statistics are also well documented, not by species fished but by major fishing gears. The estimated catches by area in 1964 are summarised in Appendix Table D5. It is to be noted that the Japanese catch in the waters adjacent to the Japanese Islands was rather bad or stagnant for the year 1964. The catches outside of the areas under consideration are almost completely excluded from tabulation except salmon; salmon catches in the western Bering Sea are included.

The total USSR catches in 1955 of the commercially important fish species amount to only 108,000 tons in the Sea of Japan and 334,000 tons in the Sea of Okhotsk. These figures seem reasonable in the light of the USSR total coastal landing reported of 300,000 tons in the Far East for that year (Mehailov 1960). The North Korean fisheries in the Sea of Japan during the pre-war periods depended exclusively on sardines and Alaska pollack. Since 1941 the sardine fishery has more or less abruptly collapsed. Therefore, the total landing from the North Korean waters would have been less than 350,000 tons in 1955 (including about 200,000 tons of Alaska pollack). The South Korean landing from the Sea of Japan in 1955 is estimated as about 100,000 thousand tons of fish, including squid. In the same year, the Japanese landing of fish species was about 600,000 tons in the Sea of Japan and 320,000 in the Sea of Okhotsk. Summing up these estimates gives total catches in 1955 in the Seas of Japan and Okhotsk of 1.1 to 1.2 million tons and 654,000 tons respectively. The figures of 1.6 and 0.87 million tons, given by Zenkevich (1963), appear to be a little high especially for the Sea of Japan, even though his figures may include the landings of invertebrates, seaweeds and marine mammals.

The catches by area in 1964 of all countries concerned are summarised in Table D1.

6. STOCK ASSESSMENT

Observations and studies, too many to enumerate, are available on fisheries resources. However, in general, straightforward stock assessment by species seems to be rather limited - especially in Japan - probably due to overwhelmingly complicated structures in fishery and in demand. Most Japanese biologists believe that the Japanese coastal waters have already been heavily exploited and are more concerned with conservation against rapid industrial development along the coasts.

6.1 Sardine (Sardinops melanosticta (Temminck and Schlegel))

Sardine was once the largest fisheries stock in Japan. The total catch along the coasts of Japan exceeded 1 million in 1932 and reached 1.6 million tons in 1936. Meanwhile the catch along the east coast of the Korea Peninsula increased also and 1.35 million tons of sardine were taken in 1937. Their abundance, however, quite abruptly declined towards the early 1940s and the Korean fisheries completely collapsed in 1943. It is now generally accepted that unfavourable changes in environment had seriously damaged sardine populations in larval stage for a few years. In the post-war period, their distribution, spawning as well as main fishing grounds, was found apparently greatly changed, compared with those in the pre-war period. At first they appeared to be recovering with gradual increase in catch to about 460,000 tons in 1951, but since then the catch has continuously decreased to 16,000 tons in 1964.

Table D3 - Present yield by area around 1964 ('000 tons rounded figures)

	Japan Sea	Okhotsk Sea	NW Pacific (5)	Total
Pelagic	280	375	1,230	1,885
Northern sp.(1)	45	375	340	760
Southern sp.(2)	235	-	890	1,125
Demersal	835	410	365	1,609
Northern sp.(3)	820	405	280	1,505
Southern sp.(4)	15	5	85	105
Other fishes	130	115	367	612
Squid and Cuttlefish	175	15	185	375
Other molluscs	25	20	300	345
Other invertebrates	30	80	70	180
Seaweeds	42	38	5	275

Notes - (1) Includes herring, salmon and saury

(2) Includes sardines, anchovy, mackerel, jack mackerel, yellowtail, skipjack and tunas

(3) Includes Alaska pollack, cod, navaga, atka mackerel, rockfish, flatfishes, sandfish and argentine

(4) Includes southern demersal fish and sand launce

(5) The Northwest Pacific as used here is the waters east of Japan, the Kurils and Kamchatka

The old documents and records now available indicate that the sardine fisheries in Japan have experienced long-term vicissitudes and that they had enjoyed prosperity during 1570-80, 1690-1720, 1800-30 and 1920-1935. Since the early 1950s, most of the fishing efforts for sardine, principally purse seiners, have been directed towards anchovy, horse mackerel and mackerel (Anon. 1966).

6.2 Anchovy (Engraulis japonica (Houttuyn))

They are distributed all along the coasts of Japan and, although they are neritic in nature, sometimes found as far as 1,000 mi off northern Japan. They spawn almost all the year round with peaks in spring and autumn. The stocks, for convenience, are broadly grouped into four, that is Northern and Southern Pacific, Japan Sea and West Kyushu stocks, but each of them is confirmed to consist of several local stocks, and they are further composed of spring and autumn broods. Cooperative studies indicate that the stocks and the fisheries are fairly localized (Anon. 1966).

The catch was long maintained at a level of 100,000 tons but since 1951 it rapidly increased and attained 430,000 tons in 1957. About 80% of the catch was taken from the Pacific coasts including Seto Inland Sea. It is further noted that about 20,000 to 25,000 tons of post-larval anchovy were taken along the southern Pacific coasts although these fisheries are at present considered to have no appreciable effects on the adult fisheries (Tanaka 1960, Hayasi 1961). In the 1960s the total catch slightly decreased to a level of 250,000 to 300,000 tons, but it is generally regarded as reflecting a decrease in demand. An increase in catch of 100,000 to 200,000 tons would be biologically feasible, provided that the demand existed (Anon. 1966).

6.3 Jack mackerel (Trachurus japonicus (Temminck and Schlegel))

The main spawning grounds exist west of Kyushu in East China Sea, along the edge of the continental shelf, where the Tsushima Current is branching off the Kuroshio Main. They are more pelagic in nature than sardine and mackerel, and the main fishing grounds extend in offshore waters from those spawning grounds towards the west coast of Kyushu and the southern part of the Japan Sea. Until 1951 the catch was rather low and below 50,000 tons in all, but in 1952 through 1958 it rose up to a level of 200,000 tons as the fishing effort shifted from sardine. Since 1957-8 technological developments led to the exploitation of new fishing grounds offshore in East China Sea and the catch again climbed to a level of 500,000 tons in 1960, as the efforts increased. In the meantime, the catch statistics indicate that the catch along western Japan was maintained at a level of 100,000 tons, accompanying some annual changes in availability.

Recently it has been noted that the catch at the edge of distribution has been decreasing and that smaller adults have increased in the offshore catch, indicating an increased fishing intensity on spawning populations, and that the catch of 0-age group has increased in the coastal waters and occasionally exceeded half of it, indicating increase, not in availability, but in fishing intensity. Conventional analysis suggests that raising the minimum size a few centimetres may result in a 20% increase in yield, but otherwise the present fishing efforts might almost reach the point of over-fishing (Mitani 1963).

6.4 Mackerels (Scomber japonicus (Houttuyn) and S. tapeinocephalus (Bleeker)

Mackerel caught in the vicinity of Japan consist of two species. Their distribution ranges fairly overlap especially south of 37°-38°N. The former, common mackerel, are distributed further north. Total mackerel catch in Japan more or less steadily increased in the post-war period, from 50,000 tons in 1947 to 500,000 tons in 1964. Regionally, however, the catch along the coasts of southern Sea of Japan and west of Kyushu has been fairly maintained, with some inevitable annual fluctuations, at a level of 100,000 tons, while the catch along the Pacific coasts from central Japan towards Hokkaido has remarkably increased since 1955 and attained a level of more than 300,000 tons in the early 1960s. That is, common mackerel, S. japonicus, was a predominant contributor to the remarkable increase in catch. Since the early 1960s the Soviet Union fisheries have operated in the Pacific off northern Japan, but unfortunately no information is available.

Common mackerel, S. japonicus, consist of three major stocks, southern and northern Sea of Japan groups and the Pacific group, the most predominant stock of the three. Their spawning grounds extend along the west coast of Japan towards East China Sea on the one hand, but the main spawning grounds are along the southern coasts of Japan, especially above South Honshu Ridge south of central Japan. Analysis of catch and effort statistics indicates their abundance there has still be steadily increasing (Usami 1965). Southeast of Hokkaido, in addition to the Soviet Union fishing efforts, the purse seine efforts have been greatly intensified since 1962. However, there seems no indication that the stock is under too heavy exploitation. The catch in the Sea of Japan appears to undulate in a few years' cycle.

It is known that farther offshore than the present fishing grounds in the Pacific young mackerel are distributed. Technological development would feasibly bring about an increase in yield of 100,000 to 200,000 tons (Anon. 1968a).

6.5 Herring (Clupea pallasi (Cuvier and Valenciennes))

Herring was once the largest stock in Hokkaido. Around 1900, about 750,000 tons of herring were caught along the coasts of Hokkaido, but since then they had generally begun to decrease. Until the early 1950s, however, occasional occurrences of a dominant year-class at intervals of 3 to 6 years, supported the fisheries for the next few years and the catch was maintained at a level of 200,000 to 300,000 tons (Ishida 1952, Motoda and Hirano 1963, Ayushin 1963). The present fisheries in Hokkaido have almost collapsed with the last dominant year-class in 1939. Meanwhile, it is observed, their spawning grounds have shifted northward and gradually diminished (Hanamura 1963).

The same is generally true for the herring stocks in the Sea of Japan along the coasts of North Korea, Peter the Great Bay and Primor'e (Hirano 1961, Motoda and Hirano 1963). The herring abundance has entirely shifted to the northern coast of the Sea of Okhotsk. Soviet biologists assume that there are two stocks there. The fisheries there had long caught only the spawning populations along the coast, but since the early 1950s have developed offshore fishing for oil-herring on the tracks of feeding migrations and the catch has remarkably increased. Evidently however, the fisheries closely depend on dominant year-classes and the catches are fairly variable from year to year. Spawning success seems to be related to peculiar hydrographical conditions in northern Sea of Okhotsk along the coast, that is, a narrow band of pack-ice along the coasts begins to melt earlier than offshore, although the timing closely depends on the climate, to provide favourable conditions for phytoplankton developments (Ayushin 1947, Kaganovich and Polytov 1950). Under such circumstances, the Soviet biologists have made only conservative estimates of sustainable yield in the northern Sea of Okhotsk.

6.6 Saury (*Cololabis saira* (Brevoort))

It has long been known, and recently confirmed by Soviet research vessels, that saury are distributed widely all over the North Pacific, mainly in subarctic waters. However, the fisheries in the Northwest Pacific have taken only those groups of saury, 3 and 4 year-old adults, on their migration south off northern Japan. Morphometrically they are composed of two different populations, which are considered to be more or less different in time and place of spawning and consequently in body length. Occurrence of post-larvae along the Pacific coast of Japan indicates their spawning primes in autumn and early spring. Unfortunately these two populations have not yet successfully followed up through their life cycle. They are assumed to distribute off northern Japan as far as 170°E, but the present fisheries cover mainly west of 150°E. The annual catch off northern Japan has fluctuated between 170,000 and 450,000 tons these last 15 years with a slight decreasing trend (Odate 1968). The Japanese biologists consider that even these two populations in the Northwest Pacific have not yet been too heavily exploited, although further offshore fishing may be economically difficult. Very recently Japanese catches have decreased very much; the reason for this is not known for certain.

6.7 Salmon (*Oncorhynchus*)

Commercially important in the North Pacific are five species of *Oncorhynchus*, that is, *O. keta* (chum), *O. gorbuscha* (pink), *O. nerka* (sockeye), *O. kisutch* (silver) and *O. tschawytscha* (king). Innumerable reports on their biology have been published in Canada, USA, USSR and Japan. They are anadromous fish ending their life just after spawning and the fisheries in the pre-war period developed along the coasts in the vicinity of their spawning rivers. It is now recognised, however, that they are quite oceanic in nature during at least more than half of their life, having unexpectedly wide ranges of oceanic distribution in the North Pacific (INPFC*Bulletins 1955-68). Together with her surrender in World War II, Japan lost all her fishing rights long established along the Asian coasts, and since then she has been obliged to depend solely on offshore fishing for salmon, although some high sea fisheries for salmon had been conducted there since 1930 (Kasahara 1963). The high sea salmon fisheries are now strictly regulated upon recommendations of two international fisheries commissions, the one between USSR and Japan, and the other among Canada, USA and Japan.

Because of their rather established pattern of spawning, any species stock consists biologically of many unit populations, too many to deal with separately. As a first and practical approximation, therefore, it is generally accepted that they are grouped into several local stocks in the light of some assumed ecological similarities and statistical conveniences. Catch statistics for those local stocks are rather well documented with reasonable accuracy, but statistics on escapements for spawning are unfortunately lacking in most of the cases. Probably because of these two circumstances, superimposed with environmental variations, high annual variabilities are usually observed around any fitted parent-progeny relationship (Hanamura 1963).

- Chum salmon: The Asian chum resources consist of the following seven local stocks, that is, East and West Kamchatka, Okhotsk District, Amur Summer and Autumn, Sakhalin and Hokkaido-Japan-Proper groups. Dominant in the spawning population are 4 and 5 year-old groups and generally they do not spawn so far upstream as sockeye. During their 2 to 4 years' ocean life, they are widely distributed across the ocean (Shepard *et al.* 1968). Recently the summer chum stocks have apparently begun to fail to reproduce themselves since about 1960.

- Pink salmon: Asian pinks consist of quite many unit populations and their spawning grounds are most widely distributed (Ishida 1967). Generally they spawn most downstream near the mouth of the river. They all mature in two years and therefore odd and even year groups belong to different and independent cycles of reproduction. During their one and a half years' ocean life, they are also distributed widely across the ocean (Neave *et al.* 1967). For convenience, they are grouped into three major stocks; East Kamchatka, Pacific, spawning along the coasts of the Sea of Okhotsk and along coasts of northern Japan, and Sea of Japan group, spawning along Primor'e Amur and west Sakhalin. Apparently most of the populations, especially those along the west coast of Kamchatka, have begun to fail to reproduce themselves since around 1960.

An overall parent-progeny relationship for three major stocks indicated a sustainable yield on the average to be as high as 227,000 tons for the odd year group and 108,000 tons for the even year group. During the late 1930s to early 1940s, about 250,000 tons of catch was maintained for odd years and about 150,000 tons for even years. It may be noted that in the post-war period the total catch has never exceeded the above estimates except for 1956 and 1958.

*International North Pacific Fisheries Commission

- Sockeye salmon: The major spawning areas are now quite limited in Southwest and East Kamchatka. The 5 and 6 year-old sockeye are dominant in the spawning populations on the Asian side. They spawn far upstream of the river with springs or lakes. East Kamchatka sockeye have a little earlier spawning prime than West Kamchatka sockeye. Probably because of reproduction failure, coastal fishing for Kamchatka River sockeye (East Kamchatka) was prohibited during 1951 through 1961. West Kamchatka sockeye have recently been maintained in an apparently lower level of reproduction than in the 1950s. Approximate parent-progeny relationships indicate the sustainable yield of Asian sockeye to be about 24,000 tons. Bristol Bay sockeye migrate westward across the ocean into the Northwest Pacific, where they are susceptible to offshore fishing, although the amounts taken are annually variable (Chitwood 1969).

- Silver and King salmon: Catches are small and largely incidental to fishing for other species.

6.8 Skipjack (Katsuwonus pelamis (Linne))

The fishing season in the vicinity of Japan begins in April or May southwest off Kyushu, moving along the Pacific coast and arrives in July or August off northern Japan. Five different groups of skipjacks migrate towards the coastal waters with some time lags though they all belong to the same trans-oceanic stock in the North Pacific (Kawasaki 1966). The group off norther Japan consists exclusively of 2 year-olds. Since 1958 the catch as well as the strength of migrating groups have been increasing. In general, skipjack have so far been fished along the edges of their distribution only. Consequently, substantial increase in yield over 120-150,000 tons at present could be expected, provided that some difficulties in transportation and processing could be overcome.

6.9 Bluefin tuna (Thunnus thynnus (Linne))

Their spawning grounds are confirmed along the axis of the Kuroshio off the Ryuku Islands (Yabe *et al.* 1966), and the young and adults are caught in the coastal waters of Japan. The catch exceeded 30,000 tons in 1956, but it now appears to be stable at a low level of 15,000 tons. No substantial increase in sustainable yield would be expected.

6.10 Yellowtail (Seriola quinqueradiata (Temminck and Schlegel))

They spawn southwest of Kyushu in central East China Sea in winter, and their larvae and young less than 10 cm are transported by the Kuroshio or the Tsushima Current together with the floating seaweeds in which they shelter. They are quite neritic in nature, but they seasonally migrate a good distance along the coasts. They have been long fished by so-called passive gears, for instance, by set nets along the coasts. Because of high commercial value, larvae and young collected alive, have recently begun to be reared by artificial feeding. The number of larvae, collected alive, has rapidly increased since 1964 and amounted to more than 33 million in 1967. In that year about 26,000 tons of commercial sized yellowtail were produced by culturing and about 49,000 tons of yellowtail were taken by the coastal fisheries. The newly developing fisheries on these larvae and young are now considered to have no appreciable effects on the old yellowtail fisheries along the coasts.

6.11 Common squid (Todarodes pacificus (Steenstrup))

Common squid is now one of the most important stocks along the coasts of Japan. In the post-war period the catch increased explosively, supported by increase in demand and technological development. The catch exceeded 500,000 tons in the early 1960s. In spite of developments in gears, however, the fisheries have experienced large annual fluctuations in availability and fishing success, and the catch has gone up and down between 300 and 500,000 tons. Conventional study seems more difficult to apply than in the case of fish populations and progress was rather slow, but basic information on spawning (Hamabe 1962), early development (Okutani 1965, Okiyama 1965a) stomach contents (Okiyama 1965a, Hamabe 1964, Abe 1965) and population structure (Ito 1965, Katoh 1964, Shintani 1965) have been steadily compiled (Anon. 1965). One of the main spawning grounds is shown by distribution of larvae of early Rhynchoteuthion stage to exist southwest of Kyushu along the edge of the continental shelf in winter, and larvae and young are transported by Tsushima or Kuroshio Currents (Watanabe 1965). During June through November the fishing grounds are situated in northern Japan, and during February to April in western Japan. Along both coasts of central Japan the seasons are in December-January and in May. Population structure is no more considered to be so simple as expected, and fishing success seems to depend closely on hydrographical conditions, favourable upwelling or convergence. More than 80% of the total catch has been generally taken along the Pacific coasts of northern Japan and Hokkaido. They are neritic in nature, especially when young, and no substantial increase in sustainable yield appears to be expected at least along the Pacific coasts of northern Japan. Along the east coasts of Korea Peninsula more than 70,000 tons of common squids are estimated to have been taken recently, but further offshore in central Sea of Japan exist possibly favourable hydrographical conditions and a wide and abundant distribution of food organisms, Paranthemist japonica, indicating a high potential productivity of common squid (Okiyama 1965a, Anon. 1965).

6.12 Alaska pollack (Theragra chalcogramma (Pallas))

In the 1960s the Japanese catch of Alaska pollack tremendously increased in the North Pacific, mainly due to new technological developments in processing and resultant increase in demand. The stocks in the Bering Sea are the main contributors to recent increase in catch. The Alaska pollack resources in the Northwest Pacific under consideration in this section have, according to Japanese biologists, all been under fuller exploitation, especially in northern Sea of Japan. They are considered to consist of several stocks (Ishida 1954, Ogata 1956, 1959). Broadly speaking there are two major stocks in the Sea of Japan, the one along northern Primor'e, West Sakhalin and Hokkaido, east of Cape Erimo, and eastward to the southern Kurils. Since the middle 1960s the stocks off South Kamchatka and around the northern Kurils have been heavily exploited.

In general, Alaska pollack do not appear to migrate so widely as previously supposed, and their respective spawning grounds have already been confirmed except for those along East Sakhalin. Because of nekton-benthic nature, they are fished by several gears, trawls, longlines and set nets. In the Sea of Japan the Japanese fish only the spawning populations and the dominant age groups taken are 4 to 5 age-groups in East Korea Bay (Tyan Ir Khan 1962) and 5 to 6 age-groups in northern Sea of Japan (Anon. 1968a). In the Sea of Okhotsk and in the Pacific, on the other hand, the feeding populations are rather largely fished and the percentage of immature 4 year-olds tends to increase in the catch. The fisheries dependent on spawning populations have recently been stable, while those for feeding populations are much more subjected to annual changes in availability, which in its turn depends highly upon the distribution of food organisms (Anon. 1968a).

According to Japanese biologists, almost all spawning populations in the Sea of Japan have been fished since 1955 and the catch by Japan has been maintained at a level of 100,000 tons since the early 1960s, with fairly stable strength of recruitment. The same is probably true in East Korea Bay. In the middle 1960s the total catch in the Sea of Japan by all countries is estimated to have amounted to about 570,000 tons and any substantial increase beyond 600,000 tons could not be expected.

In the Sea of Okhotsk, the fishing grounds have recently extended off the northeast coast of Sakhalin. In Taraika Bay the Japanese catch has increased to a level of about 70,000 tons. There and northward floating ice has rejected any access to the spawning populations, but recently some decreases in return to increased input of efforts have been noted. Further south along the Okhotsk coast of Hokkaido, the catch and the catch per effort have both decreased since 1964. The spawning grounds appear to be more or less evenly distributed along the southwestern corner of the sea, in contrast with several concentrated spawning grounds in the Sea of Japan. The stocks off Southwest Kamchatka are fished in April-May during their spawning season. The catch exceeded 45,000 tons in 1966, but the percentage of smaller fish has been observed to increase together with slight decrease in the catch per effort. In the middle 1960s the total catch estimated in the Sea of Okhotsk was only about 220,000 tons, less than half of that in the Sea of Japan, but all of the established fishing grounds have already indicated some signs of full or over-exploitation. There appears to exist further north some virgin stocks to be exploited, but floating ice seems to have prevented any efficient fishing grounds from developing there.

In the Pacific south of Hokkaido the catch increased to a level of 90,000 tons in all. They are mostly taken by gill-nets. Increases in yield are due to increases in effort and in gear efficiency, but the stock itself is also recognised to be increasing west of Cape Erimo. It is also noted that the dominant groups caught are 3 to 4 year-olds spawning for the first time. The Japanese catch off Southeast Kamchatka has recently increased and exceeded 100,000 tons in 1966. The catch per effort has also increased more than expected from increase in gear efficiency and the stock itself is concluded to be increasing. Biological information is still too limited to conclude how much they are sustainable for these stocks, but the present level of yields will be maintained for some time.

6.13 Pacific cod (Gadus macrocephalus Tilesius)

Pacific cod are widely distributed in the Northwest Pacific. Total catches were 85,000 tons in the middle 1960s, but the resources consist of many local stocks, each of which seems to be too small to develop specialised cod fisheries as in the North Atlantic and easily inclined to be over-exploited. Most cod are taken incidentally and consequently population study is scanty except for a comprehensive biological study by Moiseev in 1953.

6.14 Navaga (Elegius novaga Kolreuter)

About 30,000 tons of navaga have been recently taken by Soviet Union fisheries. Some are incidentally caught around Hokkaido by the Japanese fisheries, but they have no appreciable importance in Japan.

6.15 Atka mackerel (Plurogrammus azonus (Jordan and Metz))

They are widely distributed in the Sea of Japan through southern Sea of Okhotsk to the northern Kurils, but they are mainly fished in the surroundings of Hokkaido. There they have been long exploited and the total catch has fluctuated greatly between 40,000 and 200,000 tons these last ten years. Atka mackerel change their habitat by stages of growth and consequently they are fished by various gears, applicable to their different habitats, that is, by trawl when one-year old young pass a few months at the bottom, by purse seine in the following spring when they feed at the surface layer and by gill nets or longlines when they have recruited to the adult populations in the rocky bottom of about 150-200 m depth (Kitakata and Kon 1968). The catches by trawl are very variable from year to year, not only due to variable strengths of recruitment, but because the fishing efforts are so often shifted towards more attractive species, Alaska pollack or flatfishes. No straightforward relationships have yet been found between the size of spawning populations and strength of one-year old recruitment.

In the light of rather complex structures in population and in fishery exploitation, biological information seems to be still short of making any stock assessment, but the biologists consider that the stocks are on the threshold of over-exploitation.

6.16 Flatfishes

Generally, they are of minor importance in the trawl catches in southern and western Japan. Along the coasts of northern Japan as well as along the coasts of the Sea of Okhotsk and Primor'e, there seem to be no predominantly abundant species distributed, although some characteristic species may be found in each of the regions under consideration. Comprehensive biological information on flatfishes in the Northwest Pacific have been well summarised by Moiseev (1953). Population studies in Japan have been confined to those species commercially important or caught in quantity in the region concerned. These are: Japanese dab, Limanda hersensteini (Jordan and Snyder) and L. schrenki (Schmidt), a flounder, Cleithenes pinetorum herzensteini (Schmidt) in Hokkaido; a smear dab, Microstomus achne (Jordan and Starks); Greenland halibut, Reinhardtius matsuurai (Jordan and Snyder); a witch flounder, Glyptocephalus stelleri (Schmidt) in the Pacific off northern Japan; a California sole (Eopsetta grigorjewi (Herzenstein); Bering flounder, Hippoglossoides dubius Schmidt) and others in the Japan Sea.

The catches of most flatfishes seem to have been maintained at a level along the coasts of Japan, but it should be noted that the flounder, Cleitheines pinetorum herzensteini (Schmidt), has recently been increasing in abundance as well as catch, in the waters around Hokkaido and in southern Sea of Japan (Anon. 1965, 1966). The Japanese catch of flatfishes off West Kamchatka is unexpectedly small (a few per cent of the total). The catch per effort indicates yellowfin sole, Limanda aspera, as recently increasing, though flatfishes generally are decreasing, but the average size of sole is still notably smaller than that observed during the 1930s.

Generally, most of the flatfishes seem to be over-exploited. An increase in sustainable yield may be expected by, e.g. increasing the average sizes of fish caught. The coastal fisheries in Japan, however, do depend on a mixture species of flatfishes of different sizes and requiring different management. Under such circumstances, simple practices of improving sustainable yield do not appear to be immediately feasible.

6.17 Other northern demersal fish

While Alaska pollack is the predominant component of the demersal catch, followed by atka mackerel and flatfishes, there are other regionally important species to be referred to, that is, a channel rockfish, Sebastolobus macrochir (Gunther) in the Pacific off northern Japan and a sandfish, Arctoscopus japonicus (Steindachner) and an argentine, Glossanodon semifasciatus (Kischinouye) in the Sea of Japan.

6.18 Sebastolobus macrochir is distributed along the Pacific coasts of northern Japan, Hokkaido and the Kurils towards East Kamchatka, on the rocky edges of the shelf (100-800 m depths). There are three local stocks in the vicinity of northern Japan and Hokkaido. Because of high commercial value, the fishing has always tended to concentrate on this species and the catch has these last ten years fallen to about half of that of the early 1950s. The size of fish in the catch was 20-25 cm in body length in 1952, but rapidly diminished and since 1956 most of the catch has consisted of immature young (7.9 cm in body length) (Mikawa 1968).

Evidently these stocks are over-exploited and substantial increase in yield can, theoretically, be expected. Difficulties, however, are that immediate needs for subsistence are still prevailing along the coasts and that their nursery grounds on the shelf are nothing but the irreplaceable fishing grounds for other species of commercial value.

Stocks of Arctoscopus japonicus are widely distributed in the Sea of Japan. The dominant age groups in the catch are 2 and 3 year-olds. In winter (November-December) the spawners consisting of 3 year-olds and older usually rush towards the coast of northern Japan and immature 2 year-olds are mainly taken along the coast of western Japan and probably along the southeast of the Korea Peninsula. Since around 1960 not only the catch but the catch per unit effort has rapidly increased and at the same time the spawning grounds have also been observed to be expanding in area (Anon. 1966).

There are two local stocks of Glossanodon semifasciatus in the Sea of Japan along the coast of northern and western Japan. Their spawning season seems to be in spring (March-April) and in autumn (September-October). The dominant age groups in the catch are 2 year-olds along western Japan and 2 or 3 year-olds along northern Japan. The catch was once reduced to a low level in the early 1960s, but recently the catch as well as the catch per effort has begun to increase again, especially for the northern stock (Anon. 1966).

6.19 Demersal fishes in the southern waters

It is a characteristic of demersal fisheries on the shelf along the coasts of western and southern Japan that there are no predominant components of the catch, in contrast to recent dominance of Alaska pollack in the northern waters. The major components are croakers, lizard fishes, sea breams, butterfishes and gurnards. Population studies have been well advanced for some of the regionally important species and almost all of those specific studies indicate that they are over-exploited in a sense that the species' potential productivity is not utilised at its maximum. In fact, the dominant age group in the catch is 0-age group for most of them. Consequently substantial increase in sustainable yield might be theoretically expected for each of them, but the situations are very complicated, not only because they are trophically related to each other, but because they are fished by several different gears. Generally the total catches of those demersal fishes seem to have been fairly well maintained at a high level with gradual alteration of species composition involved.

6.20 Sand launce (Ammodytes personatus Girard)

They are very widely distributed along the coasts of Japan, but the regions where they are fished for in quantity are rather limited to Seto Inland Sea, the Sea of Japan coasts of Hokkaido and some Pacific coasts of northern Japan. They like sandy bottom and rapid tidal currents, and spawn into the sands in winter. The total catch in Japan has, these last ten years, fluctuated between 50,000 and 110,000 tons, although the reason why has not yet been well understood. Demand as human food has been decreasing, but that for reduction has increased as artifical feeding of, for instance, yellowtail larvae develops.

Analysis of stomach contents of fish-eaters along the coasts indicate sand launce as one of the abundant species to be further exploited in the vicinity of Japan.

6.21 King crab (Paralithodes camtschatica Tilesius)

These are more neritic in nature than tanner crabs. Most of the catch in the region comes from off West Kamchatka. About 25 to 26 million king crabs have recently been taken there by USSR and Japan. The biologists in both countries have agreed that under prevailing conditions no substantial increase in sustainable yield over present catches could be expected (Anon. 1966). Some king crabs have also been taken on the east side of south Sakhalin and east of Hokkaido near the southern Kurils.

The fisheries on all of these stocks, as well as tanner crabs in the vicinity of Hokkaido and northwards, are now underestrict regulation by an agreement between USSR and Japan.

6.22 Tanner crab (Chinoecetes opolio)

They are distributed in a wide depth range of 140-600 m in the vicinity of Hokkaido. The same is probably true in southern Sea of Japan of western Japan. Tagging experiments in southern Sea of Japan indicate those in benthic life do migrate vertically by season but do not so much horizontally. The catch in the vicinity of Hokkaido amounted to about 20,000 tons in 1967. The catch in Sea of Japan, especially off western Japan, rapidly increased over 10,000 tons together with an increase in fishing effort in the early 1960s, but recently some warning signs of over-exploitation have been observed, such as decreased return per effort (Annual Report 1969).

6.23 Whales

The Japanese resumed offshore whaling in the western North Pacific and western Bering Sea in the 1950s. Operations had expanded progressively eastward since 1959 and now cover the whole North Pacific. The number of whales taken by the Japanese mothership whaling in the North Pacific increased from 3,352 in 1959 to 6,484 in 1966. Meanwhile, the Soviets increased their emphasis on whaling in the North Pacific in 1963 when two new factory ships were further invested. The number of whales killed by the Soviets has annually increased from 1,881 in 1959 to 12,386 in 1966 (Chitwood 1969). The species breakdown by countries of the whales taken in 1966 is as follows (IWC Statistics):

Table D4 - Whale catches in the Northwest Pacific in 1966

	Fin	Sei	Sperm	Other
Soviet mothership	1,347	1,545	9,476	-
- landbased	-	-	-	-
Japanese mothership	1,266	2,208	3,000	-
- landbased	104	311	2,101	8

The stock assessment of whales in the North Pacific has been carried on since 1962 by the IWC working group. The stock of blue whale in the North Pacific is not large, and in the early 1960s it rapidly decreased and the kill has been prohibited for a period of five years from 1966. The kill of fin whales has recently exceeded the presently sustainable yield, on the average about 1,640 calculated for the four regional stocks combined. The assessments indicate that stocks in the eastern North Pacific are below the level giving the maximum sustainable yield. A few regional stocks are assumed for sei whales and the sustainable yield is under intensive study. There still seems to be some surplus available, which would be used up in a few years under the present rate of exploitation. The maximum sustainable yield is estimated to be probably between 1,000 and 2,000 (Nineteenth Report of the IWC 1969). Three regional stocks are assumed for sperm whales and, because of ecological complexities, information now available is still short of making any reliable estimate of the maximum sustainable yield. The recent catch appears to be substantially excessive for males, if not for females, over the sustainable yield at present. So far as the Japanese land-based whaling is concerned, no sign of decrease has yet been observed for sperm whales, not only biologically but in the trends of population indices.

7. DISCUSSIONS AND SUMMARY

7.1 General

The present yield, as tabulated in Table D1, may not clearly indicate any predominance of pelagic species over bottom living animals. The following re-tabulation, however, will show up one of the features in the Northwest Pacific, where the Alaska pollack is shown distinctly from demersal fish. Squid is transferred into the category "pelagic" (this is disputable, as the category itself might also be), because of their rather nektonic nature and thus the category "demersal" consists of those species alone, which are more or less bound to the continental shelf, including crustaceans and molluscs other than squids.

Table D5 - Present yield in the Northwest Pacific (in '000 tons) (based on 1964 data)

	Sea of Japan	Sea of Okhotsk	NW Pacific	Total
Pelagic (a)	455	390	1,145	2,260
Semi-pelagic (b)	570	220	90	880
Bottom animals (c)	320	278	613	1,210
Other fishes	130	115	367	612
Subtotal	1,475	1,019	2,516	5,012
Seaweeds	42	38	195	274

Notes - (a) Pelagic fish, plus squid

(b) Alaska pollack

(c) Demersal fish, less Alaska pollack, plus bottom invertebrates

It is now evident, although some demersal species such as sharks and skates still remain in "other fishes", that the "pelagic" species predominate over the "demersal" species in the present yield. Summing up the stock assessments by species in the above table, it is also noted that an increased level of sustainable yield may be expected for some of those "pelagic" species, but not for the "demersal" species, most of which have already been under intensive exploitation.

The summary also indicates other features, that is, unexpectedly considerable differences between regions. First, there is a remarkable regional difference in the "demersal" yield, especially when the areas of the continental shelf are taken into account, although the slopes are now being exploited. Excluding the shellfish yield, particularly large along the Pacific coast of southern Japan (another regional feature in itself), gives the "demersal" yield by region as follows:

Table D6 - Estimated potential of demersal fish

	Sea of Japan	Sea of Okhotsk	NW Pacific
"Demersal" yield(1)('000 tons)	280	252	229
Shelf area ('000 km^2)	196	580	134
Yield/area (tons/km^2)	1.42	0.43	1.70

Note - (1) Alaska pollack, together with sharks and skates, are excluded

Apparently, the "demersal" yield per unit shelf area is very low in the Sea of Okhotsk. In comparison, the demersal fish yield per unit area in the North Sea is given roughly as 1.3g/m^2/year (Steele 1965). A compilation by a Japanese colleague gives the demersal yield along the Pacific coast of southern Japan, excluding shellfish (there is in fact no yield of Alaska pollack there) to be as high as 2.87 g/m^2/year (Ikeda MS).

It is much more difficult to compare the "pelagic" yield between the regions, but it appears to be especially low in the Sea of Okhotsk. The "pelagic" yield in the Sea of Japan may seem quite high but potential may be even higher, bearing in mind that the sea has produced nearly 2 million tons of sardines besides fair amounts of other species.

The category "other fishes" is not strictly comparable between the regions. However, it doubtedly still reflects how much the coastal resources are now exploited. Habitat localization the populations, one of the ecological features of the fauna in the Northwest Pacific (Moiseev 55), appears to be particularly the case with the coastal resources as well as the demersal tocks. Probably those resources, consisting of localized small units, are not so rewarding or tractive to the highly concentrated investment. Exploitation of those species needs the support local demands along the coasts.

7.2 Comparison with basic productivity

Direct measurements of primary production are still too fragmentary compared with information vailable on standing crops and biomasses, and too far from satisfactory coverage in time and space allow any reliable estimate of annual production. A trial estimation, however rough and unsatisactory it may be, would be useful in stimulating understanding of the nature of organic production the Northwest Pacific. Throughout the literature reviewed there still appears to be some concepual confusions in usage on standing crop or biomass and production. A high standing crop or biomass es not always imply a high rate of production. The standing crop or biomass is a temporary balance tween the processes of increase and decrease and if it remains level the process of increase must balanced by an equivalent decrease (Currie 1958). This is one of the yardsticks, and may be the ly one, in what follows.

7.3 Kuroshio region

There are no distinct seasonal variations in the zooplankton biomass observed, except for some lines towards offshore (Motoda and Marumo 1963). Some reservations should be made regarding the pawning grounds of some major pelagic resources which extend west or southwest of Kyushu along the roshio in late winter through early spring since the nets used may not sample this part of the oplankton very efficiently. If we assume the possible sustainable zooplankton biomass to be 50 100 mg/m^3 in the upper 100 m depth, where the majority is considered to be present (section 3.2), en the daily metabolic requirements in terms of carbon will be calculated to be at least 0.12-0.24 gC r unit water column* using "zooplankton equivalents" (Cushing *et al.* 1958) and a mean daily metalic requirement in terms of carbon of 12% of the mixed zooplankton dry weight (Menzel and Ryther 961a). On the other hand, the daily gross primary production in summer is directly measured to be .36 gC/m^2 on a clear day and 0.29-0.31 gC/m^2 on a cloudy day (section 3.1). Assuming the daily te of respiration as 40% of the gross production on a clear day in the tropic and the sub-tropic ters (Steeman Nielsen 1958), the net primary production there is estimated to be at most 0.22 gC/m^2/y. At first glance it appears that also in the Kuroshio there exists a similar balance as obsered in the Sargasso Sea (Menzel and Ryther 1961). However, this is probably not valid for the roshio because the balance, as in the Sargasso Sea, implies little or no net production of the ooplankton themselves sufficient to feed possible populations of the higher tropical levels. oughly, two possible interpretations are, in other seasons, the phytoplankton production is much igher to produce zooplankton surpluses sufficient to feed possible higher trophic populations easonally, or the zooplankton themselves are feeding on something other than phytoplankton. In he Kuroshio the phytoplankton develops in late winter through spring (section 3.1). This is quite normal condition (Cushing 1959a) and has also been observed in the Sargasso Sea. A possible ifference is that the phytoplankton crop in the Kuroshio increases as the transparency is appreciably educed (section 2). Probably this winter blooming would have resulted from mixing to greater depths nd the resultant enrichment of the euphotic layer, inconsistent as it is with Sverdrup's theory that his factor is responsible for low winter production further north (Menzel and Ryther 1961). Of ore concern here is the fact that the net primary production would have far exceeded the grazing ate of the zooplankton for some time, and that such a high rate, however, of net primary production ight not continue for long without subsequent increase of grazing because of the resultant reducion of incidental light energy. In the case of the Kuroshio region some advective effects must be urther taken into consideration, but even so this winter blooming seems to be an indication of an mbalance in the production system. This is no more than a guess at present and it is firmly xpected that the recent Cooperative Survey of the Kuroshio will disclose the nature of organic roduction there more precisely.

The average rate of net primary production throughout the year does not appear so much higher han 0.22 gC/m^2/day that the second possible interpretation might be completely discarded. Of ourse, the rate of production would increase towards the coasts. Production under deficient utrient content in the sea water, one of the features of the Kuroshio, will be referred to later.

7.4 Oyashio region

The zooplankton biomass varies considerably according to season, and is generally less than 0 mg/m^3 in winter, except that there are occasionally observed biomass larger than 100 mg/m^3

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down to 100 m depth

southeast of Hokkaido, up to 250-500 mg/m^3 in summer (section 3.2). We should also take into account that, in the Oyashio region, the fishing grounds are exploited in summer for the major pelagic species, such as squid, mackerel, salmon, skipjacks and later of saury. Unfortunately, detailed and summarised information is not readily available, but their food requirements would undoubtedly amount to a considerable quantity. To meet not only their basic requirements but also growth requirements, and for the zooplankton to sustain themselves - though this is not always necessary - a more considerable amount of net production must be assumed for the zooplankton. The zooplankton biomass of 250-500 mg/m^3, whether sustainable or on the average under grazing, would daily require at least 0.61-1.20 gC per unit water column, assuming the majority present in the upper 100m depth. The "ladder of migration" (Vinogradov 1962) being taken into account, more metabolic requirements must be assumed. The gross primary production, directly measured in summer, on the other hand, is 0.83 gC/m^2/day on a clear day and 0.66-0.71 gC/m^2/day on a cloudy day (section 3.1). Assuming the same daily rate of respiration as before, the net production in summer is not likely to be more than 0.50 gC/m^2/day. Even the daily metabolic requirement of the zooplankton biomass far exceeds the daily net primary production. This fact, however, is not so surprising. Generally, in the temperate waters the phytoplankton crop is grazed down in summer (Cushing 1959a, Heinrich 1962). Thus, the phytoplankton crop in the Oyashio shows a bimodal seasonal variation, typical of temperate waters, but the rate of net primary production could be considered to remain fairly high during spring through autumn. Probably vertical mixing to the greater depths over the euphotic zone in winter will result in a low production (Sverdrup 1953). Assuming the phytoplankton produce enough to feed the zooplankton biomass of 50 mg/m^3 in winter, then the daily rate of net primary production is calculated to be 0.12 gC/m^2. It does not appear unreasonable. Very roughly, the daily rate of net primary production throughout the year is thus estimated as 0.40 gC/m^2.

One of the features in the Oyashio is that vertical mixing in winter usually stops at the depth of the permanent halocline (section 2). In other words, the nutrient contents in the layer are supposed to indicate the nutrient contents in winter, just before the phytoplankton bloom in spring. The surface nutrient contents in summer, on the other hand, are supposed to indicate a balance of active photosynthesis in spring through summer. On these assumptions, greatly simplified here for convenience, the daily rate of nearly net production was calculated as about 0.22 gC/m^2 at the outskirts of the Western Subarctic Gyre off Southeast Kamchatka (Sugiura and Yoshimura 1964). Apparently it is very low compared with other independent and direct measurements (Koblentz-Mishke 1965, Kawamura 1963). It seems that the difference can only be explained, not by conventional decomposition by bacteria, but by some more rapid internal mechanism, that is, rapid regeneration of nutrients by zooplankton, well established as it is today (Ketchum 1962). In general, in the Oyashio region the spring bloom starts on winter replenishment of the surface water, but the nutrient being sooner or later almost exhausted, the primary production is considered to continue on until autumn, supported by internal supply. In the Kuroshio also the primary production proceeds under almost consistently deficient nutrient contents, probably through the same internal supply. There is, however, a point to be considered here. In the Kuroshio, vertical mixing in winter undoubtedly reaches the really greater depths by vertical instability coupled with turbulence. In the Oyashio, on the other hand, it proceeds downwards beyond the euphotic layer but is prevented by the permanent halocline at the depths of about 200 m. The question is thus: how are the nutrients brought up to the surface from the so-called "store house"? The "ladder of migration" of the deep sea zooplankton by Vinogradov (1962) is an interesting observation from the point of view of how the primary production feeds those deep sea zooplankton. However, it seems to fall short of, or to be of little significance as, a mechanism of bringing up the nutrients from the store house.

7.5 Sea of Japan

More or less significant features are found in winter. Zooplankton biomass in winter (December to February) in the upper 200 m remains fairly well developed in the central part, amounting to 30-500 mg/m^3 (section 3.2). Unfortunately, no relevant measurements of primary production are available, but fairly high standing crops are observed in February in the central part (section 3.1). Assuming that both of them are sustainably high, the rate of primary production could never be low: it must more than balance out grazing by zooplankton. It appears to be very closely related to the hydrographical conditions, that is, the nature of vertical mixing in winter. Turbulent vertical mixing in the temperate waters probably results in a low level of primary production, but vertical circulation will work differently. In the Sea of Japan indeed an upwelling or surface divergence is theoretically suggested in the central part with sinking along the shelf (Fukuoka 1965). This kind of physical process appears to occur as well in the Northwest Pacific southeast of Hokkaido in winters. Turbulent vertical mixing due to surface cooling would occur regionally, but the generally low level of the standing crops and observed low rate of production (Sorokin and Koblentz-Mishke 1958) in winter, or more precisely, before spring bloom nearer to the coast, in contrast to the fairly high rate of primary production, could not otherwise be satisfactorily explained. The so-called spring bloom along the coast probably will not start until the surface stratification develops to some extent. No information is available on how the much earlier blooming in the offshore waters proceeds on into the so-called spring blooming in the Sea of Japan. The processes appear to be somewhat over-simplified in some of the literature (Meshcheriakova 1960, Heinrich 1962). The question is now what feeds on these zooplankton in winter. A suggestion might be found in the unusual (according to the author) vertical zooplankton distribution in winter in the north (Zenkevich 1963). The highest concentration may be found in the upper 25 m layer. The biomass rapidly decreases within the 100 m to 200 m layer and then deeper down it becomes considerably richer (section 3.2). It seems that there is practically no other possible population than the Alaska pollack. At a guess, concentrations of the Alaska pollack in winter appear to be more or less related to this kind of hydrographical condition not only in the Sea of Japan, but in the Northwest Pacific.

During the spring bloom, some very high rates of gross production have been observed in the north (section 3.1). Generally speaking, however, the seasonal variation in the standing crop does not appear to be so great (Ohwada and Ogawa 1966). The zooplankton biomass in summer is higher in the north than in the south, but is not so high as in the Oyashio, being about one-third or less of the latter. In the south, it appears comparable to the biomass in the Kuroshio. Assuming the daily rate of net primary production to be about two-thirds of the Oyashio (0.50 gC) for the northern two-thirds of the sea and comparable to the Kuroshio (0.20 gC) for the southern one-third during spring through autumn and, very roughly, 0.60 gC for the central one-third and comparable to the Oyashio in winter (0.12 gC) for the remaining two-thirds in winter, then the average daily rate of net primary production throughout the year will be calculated as follows:

$$\frac{3}{4} \times (0.50 \times \frac{2}{3} \times \frac{2}{3} + 0.20 \times \frac{1}{3}) + \frac{1}{4} \times (0.60 \times \frac{1}{3} + 0.12 \times \frac{2}{3}) \doteqdot 0.20 \text{ gC/m}^2$$

or 105 gC/m^2/year

In the Sea of Japan it is observed that many of the zooplankton species sink down to much greater depths than usual in the Pacific (Section 3.2). Therefore, it may be particularly inappropriate to consider the zooplankton biomass in the upper 100 m depth alone. If the calculation is made to a greater depth then we must assume the primary production to be greater. In the Sea of Japan, however, there is no permanent cline observed as in the Oyashio or in the Sea of Okhotsk. Vertical mixing in winter undoubtedly proceeds into the so-called store house of the nutrient. There a higher rate of primary production is certainly unreasonable. The problems seem to exist rather in variable delay, or sometimes complete deficiency, of the populations of appropriate higher trophic levels.

7.6 Sea of Okhotsk

Information is most scarce for the Sea of Okhotsk. First, the sea is almost all covered with floating ice in winter, one of the outstanding features to be considered. The northern and the northwestern 44% of the sea is ice-bound during almost half of the year (estimated from P. Ushakov's figure "Mean limit of floe-ice" Fig.335, p. 697, Zenkevich 1963). This severe climatic condition is evidently one of the determining factors of organic production in the sea.

The zooplankton biomass in the southern part is observed to be fairly large in summer and about 180 mg/m^3 on the average (about a half of the Oyashio). The phytoplankton crops are reversely low in the offshore waters (Kawarada *et al*. 1966). The seasonal variations of both appear very similar to those in the Oyashio except in winter, but the rate of primary production might well be regarded as generally lower than in the Oyashio. In the north, the phytoplankton start to bloom earlier along the coast, as previously mentioned in relation to herring spawning, and no autumn peak is observed. The relatively high average biomass in summer of 300 mg/m^3 (Moiseev 1955) indicates that the rate of primary production remains fairly high throughout summer, on the one hand, and relative scarcity of the grazing animals of higher trophic levels, on the other. Here again, the importance of the permanent halocline must be emphasised and recommended as a subject for further biological study. A little differently in the shallower basin than in the Oyashio, it should be more directly related to the benthic productivity also.

Assuming the daily rate of net primary production to be comparable to the Oyashio for the northern 44% of the sea during half of the year and a half of the Oyashio for the remaining southern 56% during three-quarters of the year, then the average daily rate of net primary production throughout the year is calculated, as before, to be about 0.17 gC/m^2 or about 62 gC/m^2/year.

Undoubtedly very rough and not at all satisfactory as they are, the above estimates of net primary production seem to be in fair agreement with, for instance, the overall estimates given by Koblentz-Mishke (1965). Possible regional differences also appear to show up reasonably, but they can all be considered to be within a range of errors. Below is a summary of relevant information:

Table D7 - Primary production in Northwest Pacific compared with present fish catches

Region	Area ('000 km^2)	gC/m^2/year	10^6 tons C/year	Present yield(1) ('000 tons)
Kuroshio	-	81.4	-	2,516
Oyashio	-	146.0	-	
Sea of Japan	978	105.9	103.6	1,477
Sea of Okhotsk	1,590	62.1	98.7	1,019

Note - (1) Excluding seaweeds, coastal cultures and marine mammals

Throughout the above, in spite of overwhelming importance, the zooplankton production has been consistently omitted from the discussions. This is mainly because of even greater scarcity of relevant information. Needless to say, scarcity here is relative to the complexities of the problem. To arrive at a satisfactory discussion of zooplankton production, it would no longer be possible to proceed as vaguely as in the case of primary production. Much more information is needed on the ecological features of at least the dominant components of the community, such as life-span, feeding habits, breeding, growth etc. (Heinrich 1962). As counter-evidence, information is also required regarding stomach contents, feeding habits, etc. of the higher trophic levels concerned.

Direct needs for further study on zooplankton, from a fishery biological point of view, derive from the important and variable role the zooplankton plays in the possible food web, through which the primary production is step by step transformed into the utilizable commercial yield (Steele 1965). Generally there seem to exist no consistently influential factors to change the primary production to any great extent, while, on the contrary, fluctuations in fishery yield are sometimes so rapid and unexpected that the fishery biologist is quite at a loss. Sardines in the vicinity of Japan seem to be one of the good examples in the Northwest Pacific. Probably the intermediate links in the food web would have played an important role in generating apparent considerable changes in fishery yields.

In considering the problem of organic production, it seems that "ecological efficiency" alone has been somewhat emphasized. For greater understanding of its nature, however, a little more attention should now be given to the other aspect of the system, regeneration efficiency. In this respect, human utilisation has quite a different implication from any natural prey-predator relationship. Further, "harvesting efficiency" is also an aspect which merits consideration.

These questions may appear to reduce the apparent significance of estimating the primary production. However, nothing essential is lost. The primary production is always the sole basis of organic production in the sea and, whatever the limitations of its significance, it is one of the valuable given characteristics of the region.

Summarising, the following points can be made:

(a) In the Northwest Pacific, the demersal fisheries resources have already been intensively exploited, except for the Sea of Okhotsk.

(b) Biologically, increases in sustainable yield will be expected for some of the pelagic resources, although the increases themselves do not appear great as follows:

(i) Sea of Japan

An increase of about 200,000 tons may be expected. The stock assessments indicate that it will consist mostly of common squids and possibly saury. The resultant total yield of 1.7 million tons appears to be still less than the maximum in the pre-war periods, but possible differences in the trophic level of the resources under exploitation would support this estimate as being reasonable.

(ii) Sea of Okhotsk

The estimate of the primary production roughly indicates that the sea could produce, as a whole, an amount comparable to the Sea of Japan. On this assumption, an increase of about 600,000 tons would be expected. The increase includes about 200,000 to 300,000 tons of Alaska pollack. The information available leaves some doubts as to how efficiently such quantities could be harvested. The remaining 300,000 to 400,000 tons probably consist of a variety of marine resources, including shellfish, as one of the ecological features of the fauna in the Northwest Pacific. Such resources, composed of localized small units, do not appear to be suitable for highly concentrated investment. Thus, here again, rapid exploitation would not be anticipated. Undoubtedly, however, this is the least exploited area in the Northwest Pacific and is worthy of further investigation.

(iii) Northwest Pacific

A sustainable increase can be expected in the Oyashio and in the mixed regions. Recruitment in common mackerel is increasing. It is difficult to be precise, but a rough estimate of 100,000 to 200,000 tons increase would be reasonable. The fisheries are exploiting only a fraction of the vast distribution of saury and skipjack resources in the North Pacific. The problem to be solved is why the respective fisheries have not yet extended offshore in front of such possibilities. Therefore, as an immediate target, it would seem reasonable to double the present yield. The yield of Alaska pollack has already almost doubled during these last few years. Consequently, it would seem difficult to realise a further 100,000 tons increase. To sum up, about 500,000 to 600,000 tons of increase could be expected in the Northwest Pacific.

(iv) Other fisheries

Salmon is in different circumstances from those resources mentioned above. Recently the yield appears to have been stable, but at a low level of reproduction. Biologically it does not seem unreasonable to assume the maximum productivity to be about twice that of recent yields. It would probably be a hard task for the countries concerned to restore productivity to such a level as was enjoyed in the pre-war period, although it could be done; their main responsibility would be to themselves and not to the world at large. I personally feel that the first step would be to find a more reasonably equitable basis for regulation. Anchovies and sand launces are now very abundant marine resources. However, demands are the limiting factors of further exploitation. Therefore, there may not be much increase in yield in the immediate future, though the potential is probably rather greater than the present catch.

(c) A considerable number of marine living resources have already been more or less intensively exploited in the Northwest Pacific, especially in the vicinity of Japan and it seems very difficult to find unexploited marine resources worthy of concentrated investment.

(d) The estimates of sustainable increase in yield, irrespective of feasibility, are summarized as follows ('000 tons):

Table D8 - Estimated potential fish catches in Northwest Pacific

		Sea of Japan	Sea of Okhotsk	NW Pacific	Whole region
Pelagic (b)	present catch	1,027	626	1,536	3,189
	increase	+ 200	+ 250	+ 550	+ 1,000
					(+ 350)(a)
Demersal	present catch	320	278	613	1,211
	increase				(+ 200)(a)
Other fishes	present catch	130	115	367	612
	increase (not specified by category)		+ 350		
TOTAL potential (rounded figures)		1,700	1,600	3,100	7,000

Notes - (a) No estimate of breakdown into area

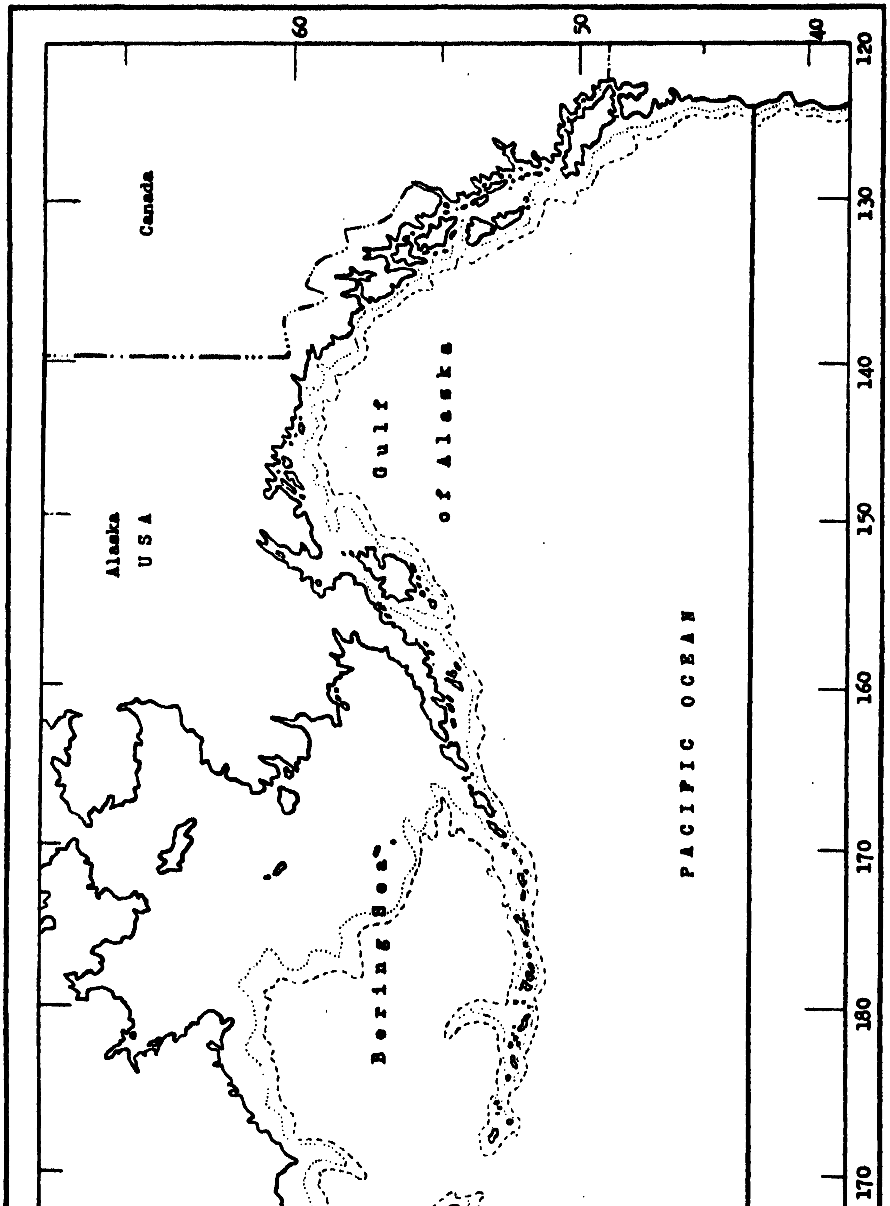
(b) Includes Alaska pollack and squid

8. FURTHER STUDIES AND REQUIREMENTS

A major difficulty in producing realistic estimates of the potential is the absence of comprehensive statistical data. Partly this is because information available in different national statistical offices is not immediately compatible, e.g. different areas are used and no central organisation is responsible for bringing the national statistics together, and partly because some of the information, e.g. regional breakdown and effort data, is not available even in national offices. A prime necessity for improved assessment is therefore the preparation of better regional statistics.

With such statistics it is likely that improved assessments, along existing lines, could be made for several stocks, especially those fished by several countries.

It also seems that a better understanding of the potential of the area could be achieved by further study of the interaction between species, and particularly between the various pelagic species around Japan.



Depth contours at 200 and 2,000 m

E - NORTHEAST PACIFIC

1. TOPOGRAPHY

As defined here, the region covers the area north of 42°N and east of 175°E, and includes the Chukchi Sea. Following Alverson (1968), the region south of the Bering Strait can be divided into a Transition Area (south of Cape Spencer), the Gulf of Alaska and the eastern Bering Sea.

The continental shelf off Oregon and Washington is rather narrow (some 40-50 km out to the 200 m contour). It is also narrow outside Vancouver and Queen Charlotte Islands, but there are more extensive areas of shelf between Queen Charlotte Islands and the mainland. North and west of Cape Spencer, the shelf widens to up to 100 km off Kodiak Island, but narrows again westward of Unimak Pass. The Transition and Gulf of Alaska regions have mountainous coasts, with a number of islands and long inlets. The eastern Bering Sea and the Chukchi Sea have wide areas of relatively shallow water.

Approximate areas of shelf are as follows (adapted from Alverson et al. 1964, Table 97) in km^2:

Table E1 - Areas of continental shelf in the Northeast Pacific

Area	Depth (fm)			Total (0-300 fm; 0-550 m)
	1-50	50-100	100-300	
Oregon - Washington	12,400	12,700	9,600	34,700
British Columbia - Southeast Alaska	33,700	37,100	33,000	103,700
Gulf of Alaska	31,900	68,300	25,400	125,700
Alaska Peninsula	49,800	30,900	16,500	97,200
Southeast Bering Sea	251,400	60,400	10,600	322,500
Northeast Bering Sea (a)	(300,000)	(75,000)	(30,000)	(400,000)
TOTAL	680,000	285,000	125,000	1,090,000

Note - (a) Area of Bering Sea east of 175°E, excluded from Alverson's Table 97

2. HYDROGRAPHY

A review of the oceanography of the sub-arctic Pacific, north of 40° lat. and including the Bering Sea is given by Dodimead et al. (1963). They have described the principal features of the water structure, the currents, their seasonal and annual variability. They identified five principal domains, based on temperature, salinity and flow characteristics; a transitional domain, extending between about 40°-45°N lat. in the Central Pacific, and widening to 35°-50°N near the American coast; a central subarctic domain, which includes the Alaskan gyre; a western sub-arctic domain extending eastward from Japan, and north into the Bering Sea; a coastal domain, extending outward from the coast; and the Alaskan Stream domain, lying immediately south of the Aleutian Islands.

South of the Aleutian Islands, the main current systems are the westward flowing Alaskan Stream and the eastward flowing waters south of the Alaskan gyre. The latter divide on nearing the American coast at about 50°N. Part moves southward to form the California Current, and the remainder moves northward into the Gulf of Alaska, returning westward in the Alaskan Stream. Favorite (1965) suggests that the Stream continues as far westward as 170°E long. where it divides sending one branch northward into the Bering Sea and one southwestward to rejoin the eastward-flowing waters.

The flow into the Bering Sea at 170°E long. moves eastward along the northern side of the Aleutian Islands, establishing a general cyclonic circulation over the deep basin. In the eastern part, cyclonic and anti-cyclonic eddies are created as the current turns northward adjacent to the continental shelf. In the northern part, the current divides, sending one branch northward toward the Bering Strait, and the other southwestward along the shores of Kamchatka, and eventually discharges back into the North Pacific Ocean. Further information on the hydrography of the Bering Sea can be found in a report by Natarov (1963).

3. PRIMARY PRODUCTION

Koblenz-Mishke (1965) has summarised the available data on primary production in the Pacific Ocean. A band of high production (over 250 mgC/m^2/day, or 100 gC/m^2/year) extends along the North American coast to the tip of the Alaskan Peninsula, and along the Aleutian Island chain including much of the offshore area of the Gulf of Alaska. The open oceanic part of the North Pacific (north of ca 40°N) is also noticeably more productive (50-100 gC/m^2/year) than the tropical and sub-tropical areas. These figures, based partly on carbon-14 measurements, should be increased to allow for the systematic underestimates in the early observations using this method (Goldman 1968).

Within the zone of high annual production, the daily production varies greatly; with the start of the spring outburst varying between February and April (Parsons et al. 1966) being earliest in the coastal areas. Studies off Washington and Oregon (Anderson 1964) and off British Columbia suggest that taken over the year the production in the latter area is rather higher. Very high values (200-400 gC/m^2/year) have been found in Puget Sound (Anderson). A complication is that both off the Washington coast and at Weather Station P in the open ocean (50°N, 145°W) the annual productivity since 1962 or 1963 has tended to decrease, being now about half the value in the early 1960s (Banse personal communication). The reason for this is not clear, but this trend, and the lack of wide seasonal and area coverage, makes any statement about annual production, and its detailed spatial variations within the generally highly productive band along the coast, rather uncertain.

Taking an average of 150 gC/m^2/year for the coastal strip, within the 500 m contour, gives a total annual primary production of 54 x 10^6 tons C/year in this part of the Transition and Gulf of Alaska areas.

In the Bering Sea, Azona (1964) using the oxygen-depletion method, and Ivanenkov (1961) found extremely high production (over 600 gC/m^2/year) in the south-eastern part, but production is less in other parts.

4. SECONDARY PRODUCTION

As in all areas, nearly all observations of zooplankton and benthos are of standing crop, rather than annual production. A summary for the whole Pacific has been given by Reid (1962).

In the Bering Sea, copepods make up 70-90% of the total zooplankton (Mednikov 1960) and the production, as wet weight, has been estimated as 115 g/m^2/year - about twice the value in the Barents Sea, and in the Northwest Pacific southeast of Kamchatka. The standing crop is rather higher in the western part (1.5-2.5 g/m^3, Vinogradov 1956), than in the southeast (0.1-0.5 g/m^3, Meshcheriakova 1964).

In the North Pacific, south of the Aleutians, total zooplankton in the oceanic region of the subarctic water mass has been found to vary from a few milligrams (wet weight) up to several hundred milligrams/m^3 in depth profiles of 150 m. The seasonal average for zooplankton volumes at Weather Station P (50°N, 145°W) varies from a low of ca 20 mg/m^3 in winter to a high of 160 mg/m^3 in summer (McAllister 1961). These values have been found to change considerably, however, over a period of several years, so that less than half the quantities given above may be encountered in some years. In coastal areas, maximum zooplanton quantities of 400 and up to 1,000 mg/m^3 have been found during the summer. In composition, approximately 75% of the zooplankton biomass at all times of the year has been found to consist of copepods, with the remainder being made up predominantly of chaetognaths, amphipods and euphasiids.

Secondary production has been calculated to vary between ca 5 and 20 gC/m^2/year and on the average to be equivalent to 20% of the oceanic primary production.

Benthos

Quantitative studies of benthos in the area are rather few with the exception of Russian surveys (Semenov 1964, Neiman 1963, Shevtsov 1964) and concentrated in rather limited areas (Shelford et al. 1935; Ellis 1967, 1967 a; Lie 1968, 1968 a). North American benthos research has been exploratory, for example early collecting expeditions such as those of the Albatross, and more recent work by the US Bureau of Commercial Fisheries. Early and recent dredging operations by the Fisheries Board of Canada are still in the process of being evaluated. Detailed studies in Puget Sound have recently been extended to the Strait of Juan de Fuca, and the waters off northern Washington (Lie 1968, 1968 a). These show that the standing crop is highest in Puget Sound (3.54 g/m^2 ash free dry weight), compared with 1.92 g/m^2 offshore. The primary production is also lower offshore. A decrease in the Puget Sound standing crop between 1964 and 1967 might possibly be associated with decreases in primary production in the Northeast Pacific in the same period.

Along the southern side of the Alaska Peninsula and the eastern Aleutians, Shevtsov (1964) found the standing crop to be mainly between 10-50 g/m^2 wet weight, with locally up to 500 g/m^2 and an average value of 150 g/m^2 in the western part, and 70 g/m^2 in the northeast. In the Bering Sea, somewhat similar densities were found in the southern part just north of the Aleutians. The standing crop was much lower in the extreme south-eastern part (in Bristol Bay) (mostly less than 10 g/m^2), but higher towards the northern part of the shelf (over 1,000 g/m^2) (Niemann 1964). However, the proportion of the benthos useful for fish food was less in the north than in the southeast Bering Sea; also the lower temperatures make it probable that the rate of turnover is slower, so that the high figures of standing crop in the north may badly over-estimate the actual annual production of benthos fish food.

Moiseev (1964) (Table E2) estimated total benthos standing crop on the shelf areas of the North Pacific as follows, distinguishing between total benthos, and benthos suitable for fish food.

Table E2 - Standing crops of benthos in the North Pacific

	Sea of Japan	Sea of Okhotsk	Bering Sea	Gulf of Alaska (a)
Total benthos (million tons)	24	210	250	60
Food benthos (b) (million tons)	10	26	11	33

Notes - (a) Includes much of the Alaska Peninsula and British Columbia - Southeast Alaska areas of Table E1 of this report

(b) Excluding benthos on those parts of the Sea of Okhotsk and Bering Sea too cold for large benthic fish populations

A striking feature of this table is the very high proportion of the standing crop in the Bering Sea which is not suitable for fish food, so that the useful standing crop in the Gulf of Alaska is some three times that in the Bering Sea, approximately the reverse of the ratio of total standing crop. Since the temperatures in the Gulf of Alaska are rather higher, it is likely that the rate of turnover is also higher, so that the ratios of annual production are still more favourable to the Gulf of Alaska. The rate of turnover is not well known. Neimann (1964) gives information on the age-composition of some bivalve molluscs in the south-eastern Bering Sea; these range up to 7 years old. Young animals seem to be under-represented in his data, and allowing for a higher mortality among these small molluscs, the mean duration of life might be around 2 years so that the standing crop is twice the annual production.

5. THE FISH AND FISHERIES

5.1 Statistics

The statistical data are generally reliable, and fairly complete. Some details of species breakdown and area fished are not generally available for the operations of some long-range factory ships.

However, no single publication gives in an easily available form statistics for all species and all countries fishing in the area. The International North Pacific Fisheries Commission (INPFC) issues an annual statistical yearbook which gives the salmon catches by the member countries (Canada, Japan, and USA) in detail, and also data on the herring, halibut and king crab fisheries, and on the Japanese bottom fishing in the Bering Sea and Gulf of Alaska, though these are not expressed in a standard form, e.g. the weight used is sometimes live weight, sometimes gutted weight, or even product weight (cases of salmon). The metric system is only partially adopted. More detailed halibut data are available from the International Pacific Halibut Commission (IPHC). Details of the other coastal fisheries of USA and Canada are available in national statistics.

A summary of recent catch statistics is given in Appendix Table E1.

5.2 The fisheries

The major long-established fisheries are those for halibut and salmon, though cod have probably been exploited for a longer period, first by a line fishery existing at the end of the last century, but more recently by trawl. The halibut fishery, using longlines, started around 1890, and quite soon had seriously depleted the stocks, first in the south, and later in the north and west (Thompson 1950). Since 1932 the catches have been controlled by the IPHC and lately catches have been around 60-70 million pounds dressed weight (30-35,000 metric tons live weight). In 1961/3 some 8,000 tons annually were taken in the Bering Sea by Japanese and other vessels, but fishing in the south-eastern Bering Sea has since been severely restricted by INPFC (a tri-partite commission involving Canada, Japan and USA).

Salmon have long been exploited along the coasts by a wide variety of gears - traps, gillnets, seines, lines, etc. - and there is a long history of national and state regulation of the coastal fishery. The pink and sockeye salmon of the Fraser River are managed internationally by the International Pacific Salmon Commission. A more recent development is the Japanese fishery for salmon on the high seas, using drift nets and longlines. Under treaty arrangements (INPFC) this is restricted to waters west of 175°W. Japanese catches at present amount to about half the combined Canadian and US catches.

The demersal fish (excluding halibut) have been exploited on a small scale off southern Alaska, British Columbia and Washington-Oregon by Canadian and US trawlers and liners. The species caught and area fished have varied (Larkin and Ricker 1964). Though there has been a steady increase in recent years, the total is still not high (30,000 tons by Canada and approaching 50,000 tons by USA (Ketchen 1967). Since the middle 1950s, fleets from Japan, and since 1959 from USSR - factory trawlers, and trawlers and Danish seiners with mother ships - have begun intensive exploitation of the demersal stocks, first in the Bering Sea, and then in the Gulf of Alaska and further south. In the early years flatfish were the main species caught (mainly yellowfin sole - ca 550,000 tons in 1961), but later attention has switched to ocean perch (nearly 500,000 tons in 1965), and Alaska pollock (over 500,000 tons in 1967, and substantially higher in 1968).

A locally intense fishery, from Oregon to British Columbia, for dogfish (peak 67,000 tons in 1944) was carried out for livers during the early 1940s, but collapsed when the market failed around 1949. Initially longlines were used, but the peak landings were taken by trawl and sunken gillnet.

The main pelagic species exploited has been the herring. The Canadian and US coastal fisheries have been in operation since early in the century (Tester 1935, Ketchen 1968). Several of the stocks in the area round Vancouver Island are heavily exploited and catch quotas have been applied as a management measure (INPFC 1961). The total US catch has tended to decrease since the 1940s; the Canadian catch increased to a peak of 260,000 tons in 1963, and decreased since.

Herring are now also exploited by Japanese fleets, using gillnets, in the Bering Sea (34,000 tons in 1966) and also by Russian vessels.

The Pacific sardine, which has its main centre of distribution further south, was also exploited in the southern parts of the present region during the peak years of its fishery, but even off California catches are now very small (Murphy 1966).

Important fisheries for king crab and shrimps have developed in the Bering Sea, and around Alaska; these and other crustacean resources and also molluscan and oceanic resources are discussed in separate reports in this series.

5.3 Stock assessment

Assessments of halibut, salmon and herring stocks have been made along the traditional lines. Estimates of demersal stocks generally have been made from the results of extensive exploratory surveys. The studies of the Pacific halibut were among the earliest assessments of any major marine stock (Thompson 1950). Later studies (Chapman *et al.* 1962, Southward 1968) have modified the conclusions in detail, but it is quite clear that the potential yield from the stocks outside the Bering Sea is of the order of 30 million pounds dressed weight, heads off (ca 18,000 tons), round fresh weight in area 2 (Transition Area), and about the same in area 3 (Gulf of Alaska). The state of the Bering Sea stocks and the relation of them to the stocks in the Gulf of Alaska is not so clear, but they are clearly small, perhaps at most one or two thousand tons, and easily depleted, so that the total halibut potential of the Northeast Pacific is in the vicinity of 40,000 tons.

Salmon

The salmon stocks have also been intensively studied (see especially INPFC 1962, 1962 a). While there are differences in views between Japanese and US scientists, these differences mainly concern the balance between the oceanic and coastal fisheries. There is no doubt that the stocks are close to being fully exploited, though the yield might, on one of the various hypotheses, be marginally increased by fishing at what is believed to be the optimum time (on the high seas, or along the coast). The important factor affecting the total yield is the number of young going to sea, which in turn is determined by the number of spawners, and the conditions in the rivers. It is probable that the conditions in the sea for feeding, etc. are sufficient to support a greater production of the number of young leaving the rivers, though since salmon are active predators, and hence well advanced in the food chain, the quarter of a million tons estimated below may be an appreciable part of the potential that could be achieved even with an unlimited supply of young.

The production of young, and hence total catch, could be increased, perhaps greatly, by positive steps taken in freshwater (improvement of spawning streams, clearing of obstructions between the sea and spawning sites, increased hatchery production). These will not be considered in the present review, which will only be concerned with increases that might be achieved by more rational harvesting, of the production from the existing freshwater situation.

It is believed that the present catches of salmon of North American origin (including catches by Japan) are only a few percent above the combined US and Canadian catches. Catching along this coast rather than by gillnetting on the high seas is believed (by US and Canadian scientists) to give some slight increase in catch. A bigger increase could be achieved if catches from each stock were adjusted to give the optimum spawning escapement.

Altogether it is probable that the potential catches, given the present situation in freshwater, might be some 25% above the present combined North American catch. Using the average catches of 1962/7 gives the following estimates:

Chinook (O. tshawytscha)	22,500 tons
Chum (O. keta)	35,000
Coho (O. kisutch)	35,000
Pink (O. gorbuscha)	100,000
Sockeye (O. nerka)	60,000
Total ca	250,000

This figure, a quarter of a million tons, makes a nice round figure as a rough estimate, though the total North American catch fluctuated around a rather higher level of around 350,000 tons between 1920 and 1940 before declining quite sharply between 1940 and 1960 (Ketchen 1968).

Herring

The state of the stocks off British Columbia and southern Alaska has been critically reviewed by INPFC(1961). The several stocks off British Columbia are certainly heavily fished. At the time of the study, it appeared that increased fishing could give a small increase in yield per recruit, but recruitment might be affected if the adult stock were further reduced, i.e. the potential was probably not much different from the average annual catches of 200,000 tons taken at that time. Since then, Canadian catches reached a peak of 250,000 tons in 1963, and decreased steadily to 53,000 tons in 1967. A moratorium was put into effect in the British Columbia winter fisheries for the 1967/8 and 1968/9 seasons. A recruitment failure following a period of heavy fishing has been a feature of other clupeoid stocks (Californian sardines, southern North Sea herring), and it may be that the true potential is rather less than 200,000 tons.

The herring in the Gulf of Alaska was, as concluded by INPFC, not fully exploited, and was in 1959 removed from the abstention provisions of the Convention. Since 1959 both USSR and Japan have taken substantial catches of herring from waters round Alaska, but these have been taken in the Bering Sea and almost certainly from different stocks from those in the Gulf of Alaska. Japanese catches quickly reached a peak of over 70,000 tons in 1961, and have since declined, but it is not known whether this decrease was due to a reduction in the stocks. Dudnik and Usol'tsev (1964) showed that two good year-classes (1956 and 1957) were in the fishery in 1961.

Other demersal fish

Some of the minor coastal stocks have been examined. Ketchen and Forrester (1966) have made a careful study of the petrale sole (Eopsetta jordani), one of the more valuable species of flatfish exploited by Canadian and US trawlers. They concluded that the stock was about fully exploited, with perhaps 10-15% increase possible through good management. Actual catches vary due to year-class fluctuation. Potential, off Oregon, Washington and British Columbia, is probably around 3,000 tons. Some of the large demersal fisheries operated by Japan and USSR have been in existence long enough to suppose that preliminary assessments could be carried out.

Table E3 - Estimated original standing stocks (in '000 metric tons) of ten major demersal species (from Alverson 1968)

Species	Transition	Gulf of Alaska	Bering Sea
Yellowfin sole	-	7	1,820
Rock sole	27	105	1,110
Arrowtooth flounder	160	395	180
Flathead sole	-	130	180
Dover sole	110	70	5
Pacific Ocean perch	780	350	140
Pacific hake	680	-	-
Alaska pollock	55	120	1,360
Pacific cod	40	70	130
Spiny dogfish	410	20	-

A major difficulty is that there have been big changes in the species sought (see Appendix Tables), first flounders (peak catch in 1961) and later ocean perch (peak in 1965) and Alaska pollock (peak in 1967). Catches of other less important (by weight) species have also reached a peak and decline, e.g. sablefish reached a peak in 1962. The simple catch per unit effort for any one species will, therefore, be a poor measure of its abundance, without more information on the objectives of the fishery, precise area fished, etc. However, a simple examination of the history of the Japanese fishery in the Bering Sea (Appendix Table E2) strongly suggests that the flounder stocks (mainly Limanda aspera) have been severely affected by fishing, that the high catches in 1960/2 came from the fishing out of an accumulated stock (perhaps of the order 1-1.5 million tons) and that the potential long-term average annual catch is of the order of the catches in the more recent years (perhaps 50-150,000 tons).

5.4 Fishery surveys

The Northeast Pacific is probably unique for the extensive surveys of demersal resources, which have taken place before intense exploitation started (Moiseev 1964, Alverson et al. 1964, Hitz and Rathjen 1965, Alverson 1968). These have provided estimates of the standing stock of the main demersal stocks. Rough estimates of the potential yield have been obtained by Alverson (1968) by multiplying the unfished stock by 0.1 or 0.2 (with exceptions for some species). Clearly the relation between initial stock and potential yield will depend on the average lifespan - the accumulated unfished stock being relatively greater when the lifespan is long. Some allowance for the average lifespan might be obtained when an estimate is available of the natural mortality, M (=total mortality in an unexploited stock) by expressing the potential as 0.5 x M x unexploited standing stock. Catches in the initial period of exploitation might be rather greater than this.

A number of estimates of natural mortality are available, though these by no means cover all the stocks in the area. For halibut, Chapman et al. (1962) believed that a value of 0.15-0.20 best fitted the data. For other flatfish estimates of 0.3 for petrale sole (Ketchen and Forrester 1966), 0.4 for rock sole (Forrester and Thomson 1969) and 0.3 for English sole (Forrester and Ketchen 1963). Except for the halibut, all these are for stocks off British Columbia. There is some suggestion that for a given species, natural mortality is lower in colder water (Taylor 1958). The data for yellowfin sole in the Bering Sea given by Fadeev (1963) do not permit an explicit estimate of mortality, but the high average age (around 9 years) would suggest a fairly low mortality. As a first approximation, therefore, the natural mortality of flounders (except halibut) will be taken as 0.3 in the Transition Area and Gulf of Alaska, and 0.2 in the Bering Sea.

Age compositions of rockfish (S. alutus) have been given by Alverson and Westrheim (1961), for the grounds off southern Alaska to Washington, and by Gritsenko (1963) for the eastern Bering Sea. These give survival rates of 68% and 75% respectively, corresponding to mortality coefficients of 0.39 and 0.29. These are probably over-estimates for the mortality over the whole population, since they would imply survival rates from 2 years old (i.e. after the period of high initial mortality) to 11 and 14 years of only 2%, whereas these ages (11 and 14 years) are the most frequent in the catches. A range of possible mortality rates will, therefore, be used 0.3-0.4 in the south areas, and 0.2-0.3 in the Bering Sea.

Other estimates of natural mortality are 0.2 for lingcod (Chatwin 1958), and 0.9 for Pacific cod (Ketchen 1964). The latter seems very high in comparison with other species in the area, and with the closely related cod in the Atlantic (natural mortality around 0.2-0.3). The high value may be due to the way in which the fishery samples the fishery, but at the same time the data on which the estimate is based (age composition of commercial samples and tagging) are rather better than for most species in the present area, or for cod in many parts of the Atlantic. For the present, 0.9 is the estimate for the Transition Area, but a rather lower value of 0.6 will be taken for the Bering Sea. Age composition data of sablefish (Anoplopoma fimbria) (Shubnikov 1963) suggests a survival rate of rather better than 50% per year (total mortality coefficient <0.7) between 5 and 9 years, but some of this may be due to fishing. It seems that natural mortality of round fish (gadoids, etc.) in the area may be rather greater than that of flatfish; accordingly a value of 0.4 will be used for Alaska pollock and hake.

If the natural mortality for the various demersal stocks is in the range 0.2-0.5, the formula above gives a range of potential annual catches of 0.5 x 0.2-0.5 x 0.5 or 0.1-0.25 x the unexploited stock - almost exactly the range used by Alverson.

The unexploited standing stocks of the main demersal species, as given by Alverson (1968), are shown in Table E3. (Although the area in the Bering Sea considered by Alverson is considerably less than the total area of the Bering Sea reviewed in the present report, the additional areas are mainly in the unproductive northern part of the Bering Sea).

From Table E3, and the values of natural mortality obtained above, the estimates of potential yield given in Table E4 can be derived. For halibut, the potential is taken from existing assessments. In addition to the ten species given in detail in Tables E3 and E4, a large number of other demersal species occur in the region, and their distribution is described in detail by Alverson et al. (1964). Most of these are relatively uncommon and in total make up a very few percent of the total trawl catches. The most important are the macrurids, which occur in deep water out to greater depths (1,150 fm) in recent surveys off the Columbia River (Alverson 1968), and the sablefish or blackcod (Anoplopoma fimbria), which is extensively exploited by a variety of gears. No precise assessment of these stocks will be attempted here; they might add perhaps 10-20% to the figures in Table E4 more in the Transition Area than in the Bering Sea.

Table E4 also contains data concerning the actual catches observed during some recent years. For some species, e.g. dogfish and yellowfin sole, the peak catches have exceeded the estimates of potential sustained yield and the subsequent history of these fisheries confirms that the peak catches could not be sustained and that the estimates of sustainable yield in the table are not unrealistic. A slightly lower figure - 200-250,000 tons - has been suggested by Neimann (1963) for the total Bering Sea flounder potential.

For the yellowfin sole, the changes in the fishery provide a check on estimates of standing stock, and potential annual yield. The catches (Appendix Table E2), after reaching a peak of 450,000 tons in 1961, dropped slightly to 350,000 tons in 1962, and then collapsed to 65,000 tons in 1963. It is reasonable to suppose that the stock abundance at the end of 1963 was only a fraction of the unfished abundance (say less than a quarter). The total catch up to the end of 1963 was 1.4 million tons; since there will have been some net addition to the stock by growth and recruitment, less natural mortality, the initial stock, if in fact it had been reduced by 75%, must have been less than 1.4/.75 = 1.87 million tons. (The actual value used of the reduction - .75 or .85 etc. - is not very critical.)

A closer estimate can be obtained by making some correction for the net addition to the stock. Prior to 1960 the removals were small, so that the population was not greatly reduced from its initial abundance, and the net addition would be small. In 1961/3 the net addition would have been larger, but no more than the sustainable yield - suppose 100-200,000 tons per year. Then the net reduction of the stock by the end of 1963 would have been 1.4 million tons minus 0.3-0.6 million tons, i.e. 1.1-0.8 million tons, giving estimates of standing stock of 1.47-1.07 million tons.

These figures are in fair agreement with Alverson's estimate of biomass, and might be expected to be a little lower, since if there are separate stocks in the Bering Sea with little interchange, the above calculation exclude those that are not exploited. However, the lowest estimate (1.07 million tons) seems rather low in comparison with Alverson's figures, especially as these, with the procedure used, are unlikely to be over-estimates. (They would be under-estimates to the extent that fish escape from the path of the trawl.) This suggests that the figure of a net natural addition to the stock of 0.6 million tons in 1961/3 of 0.6 million tons was too high. In 1963 at least the net natural addition must have been not very different from its maximum value.

Table E4 - Potential annual yields from the major demersal stocks (in '000 metric tons)

Species	Assumed M(a)	Potential				Peak catch		1967 Catch
		Transition	Gulf of Alaska	Bering Sea	Total(b)	Weight	Year	
Yellowfin sole	0.2-0.3	-	1	180	181	550	1961	178
Rock sole	0.2-0.3	4	15	110	129	8	1964	8(e)
Arrowtooth flounder	0.2-0.3	25	60	20	105	39	1964	18(e)
Flathead sole	0.2-0.3	-	20	20	40	11	1964	5(e)
Dover sole	0.2-0.3	15	10	0.5	25	9	1963	4(e)
Halibut	0.2	18	18	2	38			44
TOTAL, specified flatfish		62	124	332	518			
Pacific Ocean perch	0.2-0.4	117-156	50-70	14-21	214	470	1965	267
Pacific hake(c)		150-270	-	-	210	148(d)	1967	148
Alaska pollock	0.4	10	25	275	310	ca700	1968	554
Pacific cod	0.6-0.9	18	30	40	88	43(d)	1967	43
Spiny dogfish		20-30	1	-	26	67	1944	
TOTAL, specified species		460	240	665	1,365			

Notes - (a) Assumed rate depends on area considered, being lower in the Bering Sea than in other two regions

(b) Central value taken when range is given for potential in individual areas

(c) Estimate from Alverson (1968) based on unpublished US and USSR studies

(d) 1968 figures not available

(e) Catch in 1967

A lower bound to the potential yield is provided by the events of 1965/7, during which Japanese catches of all species of flounders increased from 42,000 to 89,000 tons (though this was a period in which the fleets were concentrating on Alaska pollock), and in 1967 USSR vessels took 120,000 tons. This suggests that the net natural additions to the population in 1965 and 1966 were appreciably greater than the catches in these years (41,000 on 67,000 tons). Together these limits define fairly closely the potential yield of yellowfin sole as around 150-200,000 tons.

Somewhat similar calculations can in part be made for the ocean perch fishery, when the total catches have declined from the peak of nearly half a million tons in 1965. Accumulated catches to the end of 1967 were about 1.75 million tons. Even allowing for some net natural additions, this suggests that the figure of 1.67 million tons for the original standing stock, given in Table E3, is rather low - though probably not very much too low, since the removals must have been a good substantial proportion of the original stock.

The Alaska pollock fishery has not yet developed so far, and preliminary figures for 1968 show that catches up till then had been continuing to expand rapidly. The 1968 total (700,000 tons) does suggest that the estimates of standing stock may be too low. This may well be so, in view of the techniques used. The Alaska pollock is not so strictly a bottom living fish as, say, the yellowfin flounder, so that in the trawl surveys a proportion of the population may have escaped the net by passing over the top. The present data are not sufficient to make any quantitative correction for this, and the uncorrected figures are used in this study, with the reservation that they are likely to be under-estimates.

The collapse of the dogfish fishery in the 1940s was in part due to market reasons (alternatives to the oil from liver), but the stock had by then been greatly reduced; this and evidence from other areas, and the low fecundity and reproductive potential of the dogfish, strongly suggest that the potential yield of dogfish (and possibly also other elasmobranchs) is an exceptionally low proportion of the unfished standing stock. The main demersal surveys have not extended into the Chukchi Sea, but some surveys have been done in the area (Alverson and Wilimovsky 1967). These show that the demersal stocks are much more sparse than south of the Bering Strait and consist mainly of small sized fish (mainly under 20 cm). The average catch per hour fishing was only about 2 kg, compared with ca 500 kg in the Washington trawl fishery.

The Russian surveys included observations on herring (Dudnik and Usol'tsev 1964) which appear to be widespread in the Bering Sea, probably split into at least two groups, spawning along the American and Asian coasts. The catches were good (up to 20 tons from one haul), and the potential is probably large.

Wide-ranging fishery operations in the surface waters in the open ocean have been carried out as part of the research on salmon (e.g. Powell and Peterson 1957, Hartt 1962) and albacore tuna (Powell *et al.* 1952). The gears used included purse-seines and gill nets. Besides the species of major interest, other species were caught, in particular pomfret (*Brama japonica*) occurred frequently (Hitz and French 1965). These catches suggest that pomfret form a considerable unutilized resource. The purse-seine used, with a length of 400 fm (ca 800 m) covered an area of about 10^{-8} times the area of the North Pacific investigated. Pomfret were most common in the late summer (August-September) when about 15-20% of the sets caught pomfret, with an average catch per set of around two fish. This would suggest a standing stock of 2×10^8 fish, assuming all the fish were in the surface layer sampled by the seine. An average weight of 1 kg would imply a standing stock of 200,000 tons and a potential of perhaps 20-40,000 tons. It is possible that this is biassed, since the seines were not pursed immediately after being set, but were held open in the direction in which the salmon were moving.

Other evidence of potential resources

The extensive trawl surveys mentioned above suggest that there are no substantial resources vulnerable to the normal bottom trawl not already discussed. The substantial crustacean and molluscan resources (king and tanner crab, shrimp, etc.) are being reviewed in a separate report. The resources excluded from the survey are, therefore, the pelagic fish - sardine, herring, capelin (or smelt), sandeels, etc. - including squid and the demersal resources in depths greater than 600 m. Quantities of sardine used to be taken in the region, as a northern extension of the large Californian fishery, but since the collapse of that fishery (Murphy 1966) the potential under present conditions of this area seems extremely small. The sardine appears to have been replaced by the anchovy; mid-water trawls off Oregon and Washington have taken up to 9 tons per hour (Alverson 1968). Jack mackerel and Pacific mackerel are other pelagic species exploited south of the area, but which probably also occur in the area. Since at least for jack mackerel the main spawning area is to the south, off California (MacGregor 1966), the potential of these stocks will be considered in the chapter reviewing that area. The tuna resources are also being reviewed separately, on a world wide basis.

The other pelagic fish presently exploited is the herring. The stocks off British Columbia to be fully used, but there are extensive stocks off Alaska, extending into the Bering Sea as noted above, and even into the Chukchi Sea (Alverson and Wilimovsky 1967). In the Transition Area, off Oregon and Washington, concentrations of Pacific saury have been found by US and Soviet scientists; it is widespread and abundant in the offshore waters of the Northeast Pacific. The potential of saury is discussed more fully in the section on the Eastern Central Pacific. Probably the resources in the Northeast Pacific are of the same magnitude as those in the Northwest Pacific, where some hundreds of thousands of tons are taken annually.

Further north, stocks of sandeels (Ammodytes) and smelt (capelin)(*Mallotus villosus*) are known to exist from incidental catches (usually in not very suitable gear), stomach contents of larger fish and seals, and occurrence of eggs or larvae. None of this information is in a quantitative form.

Eggs and larvae

The surveys of fish eggs and larvae in the Bering Sea in the late summer of 1958 and the spring of 1959 have been summarised by Musienko (1963). The most abundant species were yellowfin sole, with large spawning concentrations south of Nunivak Island, and pollock with spawning concentrations along the shelf west and south of the Pribilofs. Capelin larvae were also widespread in the south-eastern Bering Sea. Ammodytes larvae were also present, but not in very large quantities, and this species, at present only valuable for fish meal, does not form a commercially valuable resource so far north.

A rather extensive (300 mi x 540 mi) egg and larvae survey was conducted by the Bureau of Commercial Fisheries Laboratory at Seattle off Washington and Oregon during April 1967. The results of this survey are as follows (H.A. Larkins personal communication).

1. Genus Sebastodes (rockfish) most abundant throughout the survey area.
2. Second most abundant were the Myctophidae (lanternfishes) which were found beyond the continental shelf.
3. Third most abundant were species of flatfish found primarily over the continental shelf.

6. SUMMARY AND DISCUSSIONS

6.1 Estimates of potential

The estimates of the demersal potentials in the different areas, taking the centre of the ranges in Table E4 and adding 10-20% to allow for other species, are given in Table E5. The figures for potential per unit area are slightly lower than those for the North Atlantic, where the estimated potential demersal yields per ha vary from 70-80 kg off Iceland and West Greenland, to 15-22 kg/ha in the North Sea and off Newfoundland, with intermediate indices of 30-50 kg off New England, Labrador and Faroes.

Estimates for pelagic species are much less firm except for salmon, which are a major element of the pelagic fauna of the open North Pacific. For the smaller shoaling pelagic fish, the only reasonable estimate is the figure of around 200,000 tons for the British Columbia herring. In this area (roughly from Cape Flattery to the northern tip of the Queen Charlotte Islands) herring are probably the major pelagic resource. Possibly the other species (Ammodytes, etc.) would contribute half as much, i.e. a total of 300,000 tons off a length of coast of ca 770 km. If the same ratio (400 tons per km) applied to the entire offshore area from the Oregon-California border to the tip of the Aleutian Chain, the total pelagic potential would be, in very round figures, 400 x 4,000 = 1.6 million tons - it is probably reasonable to assume that the potential of these species is less a function of extent of shelf than of length of coastline. Approximately equal quantities might occur in the Transition Area and in the Gulf of Alaska.

Further extrapolation to the Bering Sea would be unjustified in view of the very different physical conditions in the area. The nearest to quantitative information on the pelagic resources are the egg and larval data, which suggest that the standing stock of demersal fish is considerably larger than that of pelagic fish. Possibly the natural mortality of the latter is the higher, which would make the potential annual yields more equal. A round figure for the potential (probably mostly herring and capelin) which is not unreasonable is 0.5 million tons. These estimates, and approximate guesses, are given in Table E5 below.

Table E5 - Summary of the potential catches from the Northeast Pacific (in '000 metric tons)

Region	Transition	Gulf of Alaska	Bering Sea	Total
Potential				
Demersal (a)	570	280	730	1,460
Shoaling pelagic (herring, capelin, saury, etc.)	(800)	(800)	(500)	(2,100)
Salmon				250
Deep demersal (macrurids)				100
Squid				(x100)
Myctophids				(x100)
Shelf area ('000 km^2)	140	220	400	
Demersal potential (kg/ha)	40	13	18	

Note - (a) Adding 10-20% to figures in Table E4 to allow for species not included in the latter table.

Also indicated in the table are the squid and myctophids, both of which probably form important resources, probably, as indicated, of the order of hundreds of thousands of tons. The demersal estimates only cover the depths of water sampled by Alverson's main trawl surveys, i.e. out to 300 fm (ca 600 m). Substantial catches have been taken at rather greater depths, particularly sablefish (though these may migrate into shallower water), and macrurids (Hayamoto and Alton 1965, Alverson 1968, Novikov 1965). In view of the moderately deep (between 300 and 2,000 m) bottom west of Washington and British Columbia, these resources might in total be large. Moiseev (1969, Table 100) gave an estimate of 100,000 tons of macrurids and others as the possible additional catch from the shelf and slope areas of the North Pacific (east and west). This seems rather low; a figure of 100,000 tons is shown in Table E5 as a rough estimate for the Northeast Pacific.

These estimates can be roughly compared with the estimates of primary and secondary production. For this, three regions can be considered separately - the Bering Sea, the coastal strip of the Gulf of Alaska and transition zones, and the open oceanic area of the North Pacific.

In the Bering Sea, the important part of the food chain seems to be through the benthos and the demersal fish. From Table E2, and assuming, as stated in that section, that the standing crop is twice the annual production, the annual production of all benthos is about 125 million tons, of which 5.5 million tons is food benthos. Probably this ratio over-estimates the proportion of the primary production that goes into non-food benthos, since the animals concerned (starfishes, sponges, etc.) contain a large amount of non-organic material. In comparison with the 5.5 million tons of fish food, the 0.7 million tons of harvestable demersal fish production seems a little high, on the basis of a 10-15% ratio of food production to fish production and noting that not all of the fish production can be harvested. The benthos production would be more in agreement with a potential of 0.3-0.4 million tons, though the precision of the estimates of both benthos production and fish potential, is such that the discrepancy is not serious, e.g. it would be easily removed if some of the non-food benthos could in fact be eaten by fish, or if the ratio of standing crop:annual production was less than 2:1.

In the coastal strip (out to 500 m) along the Gulf of Alaska and the Transition Area, the primary production was estimated to be equivalent to a carbon fixation of 54×10^6 tons. At a 10% transfer rate, this is equivalent to 5.4×10^6C tons of herbivores, and 0.54×10^6C, or 5.4×10^6 tons wet weight of first stage carnivores. If most of these are fish (demersal or shoaling pelagic), and half the production can be harvested, the agreement is remarkable with the estimated potential of 2.55×10^6 tons. The agreement is almost certainly fortuitous; the fact that some of the potential is based on primary production further offshore than 500 m being balanced by the fact that not all the carnivores are fish, and that many of the fish concerned are to some extent secondary carnivores.

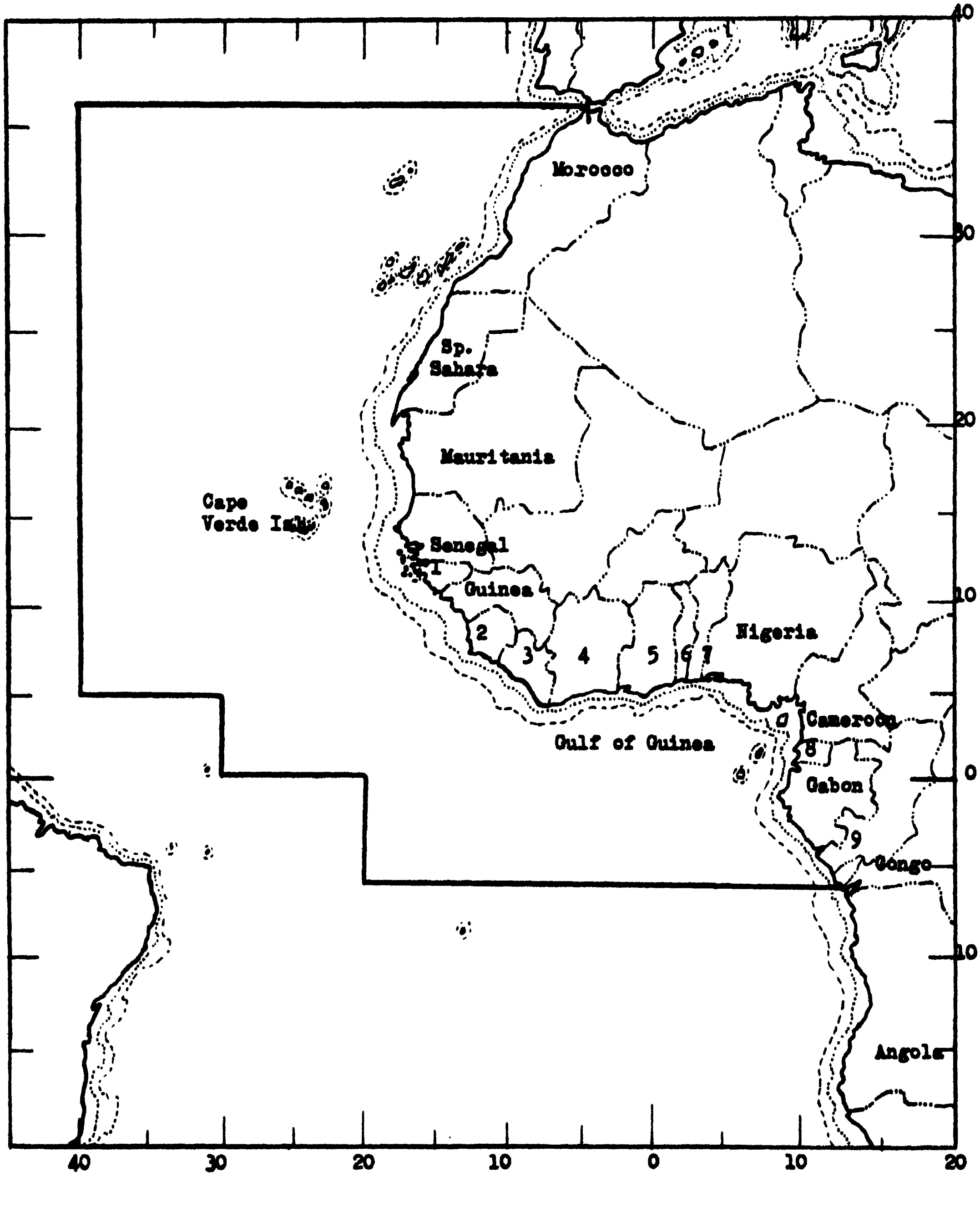
In the open ocean the primary and secondary production have been estimated as 50-100 and 5-20 gC/m^2/year respectively. In round figures the area of the North Pacific east of 180°, and north of 42°N is 5×10^6 km^2. This implies total primary and secondary production as 250-500, and 25-100 $\times 10^6$ tons C/year respectively. These figures are in fair agreement, given a transfer efficiency of 10-20%. If the production of first stage carnivores is 15% of zooplankton production, and carbon is 10% of wet weight, this gives a total annual carnivore production of 40-150 $\times 10^6$ tons, say 100×10^6 tons. These, in the open ocean, are mainly small fish and euphausids. The commercial species, mainly salmon, are at least second stage carnivores, whose annual production, at 10% efficiency, is estimated as 10 million tons. Again, supposing half of this might be harvestable, this suggests a potential of 5 million tons - of unspecified second stage predators, which are not necessarily economically harvestable animals. This figure may be compared with the estimate of 0.25 million tons of salmon under present conditions, and earlier harvest of up to 0.4 million tons. Since salmon are not the only predator in the open ocean, and may lie in part even further along the food chain, the figures are not inconsistent.

6.2 Requirements for improved estimates

Though the fisheries in the region are carried out almost exclusively (a small fishery by the Republic of Korea has begun) by developed countries with good statistical systems, the statistics of the region are not available in a simple form. Future studies of the present kind would be greatly eased if a regional statistical bulletin existed, giving the total catch by all countries, with accounts and consistent regional breakdown.

The large trawling fisheries, especially for yellowfin sole, and for rockfishes have now been in existence long enough for more detailed and accurate assessments to be made of the effect of fishing on this stock. The present estimates of the demersal potential are based almost entirely on data of standing stocks. Changes in these, estimates from research surveys, or otherwise, and changes in the age and size composition of the stock should be more carefully examined.

The estimates of pelagic resources are less accurate, and could be improved by direct estimation of standing stock, e.g. from acoustic surveys, or examination of available egg and larval data.



F - EASTERN CENTRAL ATLANTIC

Depth contours at 200 and 2,000 m

Other countries include:

Portuguese Guinea
Sierra Leone
Liberia
Ivory Coast
Ghana
Togo
Dahomey
Rio Muni
Congo (Brassa)

INTRODUCTION

The oceanography and fishery resources of this area have been discussed at two international symposia - at Abidjan in October 1966, dealing with the tropical Atlantic, and at Tenerife in March 1968, dealing with the area between Dakar and the Strait of Gibraltar. The proceedings of these meetings, and the papers presented at them, give information of the resources of the region in great detail, and have been extensively used in preparing this summary review.

1. TOPOGRAPHY

As defined here, the region covers the eastern Atlantic from the latitude of the Strait of Gibraltar (36°N) to the mouth of the Congo(6°S).

For fishery purposes the joint ICES/ACMRR Working Party (ACMRR(FAO) 1968) suggested that the region falls into two major divisions: a northern, sub-tropical region, between 20° and 36°N, and a tropical region. Each of these could be further divided for statistical and other purposes as follows:

A. Northern (sub-tropical) area

1. Morocco Coastal division lying between 36° and 26°N lat., east of 13°W long. and a rhumb line from 29°N lat., 13°W long. until 26°N lat., 16°W long.
2. Canaries/Madeira Insular division, comprising the rest of old (ICES) "Xb" and old "XIa" (western border along 20°W long.).
3. Sahara Coastal division lying between 26° and 20°N lat. and east of 20°W long.
4. An "oceanic" division lying between 36° and 20°N lat. and 40° and 20°W long.

B. Southern (tropical) area

1. A Cape Verde Coastal division lying east of 20°W long. and between 20° and 10°N lat.
2. A Cape Verde Insular division lying between 20° and 10°N lat. and between 30° and 20°W long.
3. A Cape Sherbro division lying between 20° and 8°W long. and between 10°N lat. and the Equator.
4. A Western Gulf of Guinea division lying between 8°W long. and 3°E long., north of the Equator.
5. A Central Gulf of Guinea division lying east of 3°E long., north of the Equator.
6. A Southern Gulf of Guinea division lying east of 3°E long., and between the Equator and 6°S lat.
7. An oceanic division, not yet sub-divided, covering all the waters of the Eastern Central Atlantic, south of 20°N lat., not covered by preceding six coastal divisions, i.e. the waters lying (a) between 20° and 5°N lat. and between 30° and 40°W long.; (b) between 10°N lat. and the Equator and between 20° and 30°W long.; and (c) between the Equator and 6°S lat. and between 20°W long. and 10°E long.

The extent of the continental shelves in the coastal divisions, down to about 200 m have been estimated in Table F1. For the southern area (south of 10°N) the total agrees well with the area - 230,000 km² between 12½°N and Angola - given by Williams (1968), of which approximately half was less than 50 m deep, and half between 50 and 200 m.

In addition, there are small areas of shallower water round the groups of oceanic islands (Madeira, Canary Islands, Cape Verde Islands, Annabon, Sao Tomé).

In general the West African Shelf is narrow, normally less than 20-30 mi, except off Rio de Oro (about 24°N), off Northern Mauritania (20°N) and from Dakar (16°N) to Freetown, Sierra Leone (8°N) where the shelf is up to about 100 mi wide.

Table F1 - Shelf areas of the Eastern Central Atlantic, within the 200 m contour

Division	Length (n.mi)	Breadth (n.mi)	Area n.mi^2	Area km^2
Morocco Coastal 36°N - 26°N	760	15 - 50	19,000	65,000
Sahara Coastal 26°N - 20°N	380	30 - 80	19,000	65,000
C. Verde Coastal 20°N - 10°N	650	20 -100	33,000	110,000
C. Sherbro Coastal 10°N - 8°W	530	15 -100	20,000	70,000
W. Gulf of Guinea 8°W - 3°E	690	10 - 40	15,000	50,000
C. Gulf of Guinea 3°E - Equator	670	15 - 50	19,000	65,000
S. Gulf of Guinea Equator - 6°S	450	30 - 45	16,000	55,000
TOTAL				480,000

The bottom of the shallow parts of the shelf off Morocco and Rio de Oro is difficult to trawl because of canyons and hard ground with corals, but there are some stretches of sand. The deeper parts (100-150 m) carry often soft sediments particularly on Arguin Bank (20°N). In the Archipelago of Cape Verde Islands, rocky grounds prevail. Patches of sand are rare.

In the tropical region south of Dakar and in the Gulf of Guinea more mud is found and the shelf becomes rather smooth. The coastline is more indented and lagoons are found all along the coast from Ivory Coast to Nigeria.

Charts of the bottom suitable for fishing use have been prepared for the area off Dahomey and Togo (Crosnier and Berret 1966), off Cameroun (Crosnier 1964), and off Gabon. Detailed maps of the bottom topography and of the sediments have been produced by various sources (Losano 1948; Collignon 1965; Maurin 1962; Miller 1960; Postel 1950; Ritshaupt 1965; Senin 1965; Navarro and Losano 1950, 1950a).

2. HYDROGRAPHY

2.1 The major surface current systems of the area have been described by many authors (e.g. Schott 1942). Off northwest Africa, the cool Canary Current flows southward, and then bends westward and merges with the North Equatorial Current. Similar in the south, the Benguela Current flows north off southwest Africa, and then westward into the South Equatorial Current. Between these major systems the Equatorial Countercurrent, and its continuation, the Guinea Current, flow eastward into the Gulf of Guinea. More recently the Equatorial Undercurrent flowing strongly eastward below the eastward flowing Equatorial Currents have been shown to be important (e.g. Neumann 1960, Voigt 1961, Rinkel 1969, Ponomarenko et al. 1967). A coastal countercurrent flowing westward under the Guinea Current off the Ivory Coast has been described by Lemasson and Rebert (1968).

2.2 The Canary and Benguela Currents narrow the tropical zone off west Africa. Maximum monthly temperatures of more than 27°C are only found in the area between Dakar and North Angola. In the sub-tropical area minimum temperatures range between 15°C (Cape Spartel) and 20°C (Cape Verde) and maximum temperatures between 21° and 27°C in the same places. Seasonal changes in temperatures do not exceed 5-7° in the sub-tropical areas, except in areas of strong upwelling, though changes of more than 8° occur in parts of the tropical areas.

Surface salinity is generally high in the sub-tropical region (>36°/oo) but lower and seasonally fluctuating along the tropical coasts. There are two major areas of seasonally reduced salinity - in the Bights of Benin and Biafra, and off the coasts of Sierra Leone and Guinea. Part of this reduced salinity is due to the influence of large rivers, and part directly to heavy rainfall.

2.3 The major part of the shelf area is below the thermocline and is exposed to water temperatures of 13-16°C. Only in the narrow equatorial region do water temperatures in 100 m depth reach 18-19°C. Therefore, in large parts of the tropical zone, a thin layer of tropical litoral and surface water species is found lying coastward and above the sub-tropical fauna which occupies the deeper, cool parts of the shelf.

2.4 The thermocline is well developed in the tropical part of the area. Above the thermocline water temperatures are >25°C; below the thermocline temperatures >19°C. The upper limit of the thermocline is 20-35 m over most of the region, but is much shallower (>12-14 m) in Senegal-Liberia. As in most tropical regions, the thermocline generally inclines downwards offshore.

The hydrographic feature of major importance to the basic productivity of the region, and hence to the fisheries, is the extensive areas of upwelling. Off the northwest coast of Africa, there is upwelling (in some parts of the Canary Current) throughout the year, though the location and extent varies seasonally, so that the effect is of a series of rather seasonal and local upwellings. These extend from south of Dakar (in the northern winter), to beyond the northern limit of the region in the summer. There are also seasonal upwelling areas in the Gulf of Guinea (Berrit 1961, 1962); Cushing (1969) distinguishes four parts of the general northern upwelling region (plus a fifth outside the region considered here) with geographical parameters as follows:

Region	Season	Length(km)	Width(km)	Area (10^3 km^2)
Casablanca - Canaries	JJASO	1,000	150	150
Canaries - Cap Blanc	AMJJAS	1,020	300	306
Cap Blanc - Dakar	ONDJFMA	700	150	105
Dakar - Freetown	ONDJF	800	50	40

3. PRIMARY PRODUCTION

3.1 The main areas of primary production are the coastal upwelling areas, and the oceanic area along the Equator. The production in each area varies seasonally in accordance with the seasonal variations in upwelling, but at the peak, production is very high, up to 5.2 gC/m^2/day off Dakar, and 2.7 gC/m^2/day off Takoradi. Outside the peak productive season, the production is low (0.2-0.4 gC/m^2/day in the above areas) (Bessonov and Fedorov 1965, Sorokin and Klaichtovin 1961, Corcoran and Mahnken 1969, Nielsen and Jensen 1959, Furnestin 1968, Wiktor 1968). Off Abidjan, Dandonneau observed an increase in primary production during the rainy season (July-August) just before the upwelling period, probably due to nutrients being washed in from the land. Because of these marked seasonal and area differences, and the relatively small number of observations, it is difficult to make estimates of the total annual primary production in the whole region purely from direct observations of primary production. Cushing (1969) has estimated the total production in some of the upwelling areas defined above taking into account the hydrographic data on the duration and intensity of upwelling as follows, in 10^6 tons C per year.

Casablanca - Canaries	?
Canaries - Cap Blanc	?
Cap Blanc - Dakar	12.19
Dakar - Freetown	3.48

3.2 Measurements of the thickness of the euphotic zone have been published by Nellen (1969). It was of about 30-40 m on parts of the shelf between Sierra Leone and Ghana, but >100 m in open ocean stations in the central Gulf of Guinea and off Cape Verde Islands.

4. SECONDARY PRODUCTION (ZOOPLANKTON AND BENTHOS)

The occurrence of high zooplankton standing stock follows quite closely that of the upwelling areas and main areas of primary production. Outside these areas, the standing crop is rather low, e.g. no more than 20 mg/m^3 in the open Atlantic (Grese *et al.* 1969), but in the upwelling areas the standing crop can be high, e.g. an average volume of 35 cm^3/100 m^3, presumably equivalent to about 350 mg^3 wet weight (Kinzer 1969). Year-to-year variations in plankton abundance off Ghana have been related to changes in the extent and duration of upwelling (Mensah 1969). In the inshore waters of Sierra Leone, Bainbridge (1960) found standing crops as high as those in Long Island Sound (35 cc/100 m^3). A general review of the plankton in the northern part of the region, including standing crop and species composition is given by Furnestin (1968).

All these observations are of standing crop. There are not the data presently available to convert these into estimates of production. It seems reasonable to suppose that in these relatively warm waters the rate of turn-over is quite high, so that the moderately high values for standing crop imply high values of annual production, though it would be difficult to put this in quantitative terms.

The same remarks apply to the benthos, when the limited number of observations have been on standing crop, and no explicit estimates of production have been made.

Benthos biomass has been measured by Longhurst (1958, 1959) in some detail for the region off Gambia to Sierra Leone (13° to 6°N). There is a general decrease in abundance with increasing depth. Off Senegal figures range from 74 g/m^2 for the 0-20 M/zone, 27.5 g/m^2 in 20-40 m and 11.3 g/m^2 in 40-60 m. Further south, figures are much lower (10-20 g/m^2 in 0-20 m), but the decrease of abundance with increasing depth is less pronounced. There is also a relation to the kind of bottom sediment, a moderate amount of silt giving the highest indices of benthos abundance. In the upwelling area off Ghana, Buchanan(1958) found up to 540 g/m^2 in sandy silt. Direct comparison of this figure with those of Longhurst should be made with care, due to differences in sampling gear, weighing techniques, types of organisms, etc. No quantitative data on benthos abundance in the northern area are available.

5. THE FISH

5.1 Statistics

Recent statistics, as available to FAO, are summarised in Appendix Tables F1 and F2, and have been published separately in more detail (FAO 1968). These statistics are subject to two main sources of error. For the long-distance fisheries, the total catch landed by the vessels of each country will be reasonably accurately known. What is often not known are the proportion of the catch not landed, including rejected fish of low-valued size or species, and the reduction in weight between catching and landing, e.g. due to gutting or other processing. More important is the fact that the area of capture may not be known, even roughly, so that some of the catches taken by long-range vessels actually taken in the present region may not be recorded as coming from the region. For example, Spanish statistics record catches according to the coastal area in which the port of landing lies. Thus, reported Spanish statistics for this region will include catches landed in the Canary Islands, but not the catches landed in Vigo and other European ports by Spanish trawlers fishing off northwest Africa. There may also be some confusion in the statistics concerning the increasing quantities of fish which are transshipped by the long-distance fishing vessels at some of the local ports, e.g. Las Palmas, or are landed for local consumption at these ports by foreign vessels. Such landings may appear in the statistics of the country of landing, or the flag country of the fishing vessel, or neither or both.

For the coastal fisheries, the problem is to determine the total catch. Where fishing is done by moderately large vessels, or the catch landed at big markets, there is little problem, but landings by subsistence fishermen at more or less isolated places along a long coast cannot be accurately recorded.

For these reasons, the statistics presented here should be treated with some reserve, especially as regards the total for some coastal fisheries, and the area and species breakdown for the long-distance fishery. In particular some of the trends in national catches may reflect no more than changes or improvements in the collection of statistics. However, it is believed that the figures for the most recent years give a reasonably reliable estimate of the total catch from the region, but see Østvedt (1969).

5.2 The fisheries

The fisheries have been reviewed in detail by an ICES/ACMRR Working Party, meeting in Tenerife in April 1968 (ACMRR(FAO) 1968). The following sections are largely drawn from their conclusions.

In the northern area, from the Strait of Gibraltar to Dakar, the catches were, in 1966, about 1 million tons. This total was taken by a number of quite separate fisheries, for different species by different countries. The estimated catches in the major fisheries were as follows:

small pelagic fish - 280,000 tons - principally sardine landed in Morocco, but also small quantities of Sardinella spp. landed in Senegal, and elsewhere.

medium pelagic fish - 100,000 tons - principally horse-mackerel (Trachurus spp.), bluefishes (Temnodon saltator) and mackerels (Scomber spp.), mostly caught by trawlers from USSR and other East European countries.

large pelagic fish - 140,000 tons - this total includes all tunas caught in the Eastern Central Atlantic, not all of which were caught in the northern part. In this total, the major species were albacore (25,000 tons), yellowfin (66,000 tons), and bluefin tuna (10,000 tons), the last being the most important in the coastal fisheries of northwest Africa.

large demersal fish - 300,000 tons - mainly a variety of sparids, breams, etc., taken by trawlers from southern and eastern European countries, but including also 20,000 tons of hake.

Cephalopods - 150,000 tons - these are taken mainly by Spanish and Japanese vessels, and include squid, cuttlefish and octopus.

other molluscs, crustaceans - 4,000 tons - there is no major fishery, though because of the high unit value the French fishery for lobsters and similar species is not insignificant.

In the southern area (Dakar to the Congo), the available evidence suggests that the demersal fish in the zone as a whole do not make long-range migrations along the coastline, but mainly move towards or away from the shoreline. For practical purposes, therefore, each exploited area of the shelf can be considered as a separate stock. These areas are separated from one another by intervening shelf areas where little fishing takes place because the adjacent country has not developed its fishery and the shelf is not rich or wide enough to attract vessels from more distant areas. The areas were distinguished in the 1968 working group report as follows:

Major demersal fishing areas	Areas with little fishing (separating the major fishing areas)
Bissagos, Guinea, Sierra Leone	Liberia
Ivory Coast and Ghana	Togo and Dahomey
Nigeria	Cameroun to Cape Lopez
Cape Lopez to Congo Brazzaville	

though larger vessels from the adjoining areas are tending to move into the lightly fished sectors.

Of the major demersal fishing grounds, the best are in areas of upwelling and of these the Bissagos ground has the largest biomass, because the continental shelf is particularly wide (200 km). Furthermore, and on a smaller scale, river mouths usually provide rich trawling grounds where large sized fish (sciaenidae, polynemidae, ariidae, skates) are caught. The best example of this is the mouth of the Congo River.

The richest prawn grounds (*Penaeus duorarum*) are in the vicinity off large river mouths or lagoon entrances to the sea, e.g. southern Senegal, eastern Ivory Coast, Nigeria. Spanish trawlers have recently developed deep-water fishing for shrimp off Mauritania, Senegal, Congo and northern Angola.

The pelagic inshore fisheries are based mainly on bonga (*Ethmalosa fimbriata*) and *Sardinella*. The presence of *Sardinella* spp. seems to be correlated with the presence of upwelling. *Sardinella* spp. are known to be abundant off Senegal, Ivory Coast and Ghana, Gabon and the Congo, and in northern Angola.

A number of general accounts of the fisheries of the region have been published including, on the northern pelagic fisheries, Furnestin (1943, 1950), Postel (1955), Furnestin and Furnestin (1968). On the northern demersal fisheries, there are many other papers describing the results of exploratory voyages, listed in Maurin and Adelbert (1968), Thomasi (1946), Belloc (1933), Letaconnoux (1959), Lozano (1948), Ritzhaupt (1962), von Brandt (1968), Maurin (1954), Domanevsky (1968), Monteiro and Lima Dias (1968); on the cephalopods, Bonnet (1968), Klimaj (1968); and on the tropical fisheries, Rossignol (1955), Longhurst (1961, 1963), Steven (1945), Irvine (1947), Poinsard (1969), Østvedt (1969), Ansa-Emmin (1968).

5.3 Stock assessment

Several authors have shown that in some localities the inshore tropical demersal fish have been heavily exploited, and no great increase in catch can be expected (Longhurst 1963, 1965; Bayagbona 1965; Poinsard 1969). "Over-fishing" has also been suggested in the most northern part of the area off Morocco (Collignon 1968). The ICES/ACMRR Working Party concluded that in the northern area following the rapid increase in fishing by long distance trawlers, the hakes and the sparids were heavily fished, and estimated potential yields with the present pattern of fishing, as 20-25,000 tons, and 150,000 tons respectively. Some increase in yields would be achieved by using a larger mesh size. Both groups, especially the sparids, include a number of different species, so that while some species or populations are clearly too heavily fished, others may be still quite lightly fished, and if appropriate management could be applied to each stock separately - larger mesh size and somewhat less fishing effort for the heavily fished stocks, but increased fishing on some other stocks - the potential catches might be appreciably higher, perhaps 30,000 tons of hake, and 200–250,000 tons of sparids.

No assessments have been made of the pelagic resources (other than tuna) of which some stocks are heavily exploited (FAO 1968), or of the cephalopods, though the Working Party found no evidence that any of these were fully exploited.

5.4 Other estimates of potential: fishing surveys

In the southern part of the region, an extensive survey of the demersal resources was carried out by the Guinean Trawling Survey (GTS) (Williams 1968). This, extending from Senegal to the Congo and out to 400–600 m depth, showed that there were appreciable demersal resources outside the heavily fished areas noted in the previous section. A substantial proportion of the catches were of pelagic species (*Ilisha*, *Sardinella*, *Caranx*, *Decapterus*, and *Trachurus*), which are not sampled effectively or consistently with a bottom trawl, and only the more truly demersal species are considered here. *Brachydeuterus*, though a demersal species, occurs not infrequently well off the bottom, and may also have been under-estimated in the surveys. These species are here considered together, though there are large regional, depth, and seasonal differences in species composition which are discussed in detail by Williams (1968, 1969)and Longhurst (1966). Durand (1967) has also duscussed in detail the changes along a fixed transect.

The GTS area was divided into 13 statistical areas, each 200 n.mi (370 km) long, and the summaries of the average catches in these areas, for the depth ranges 15–50 m and 50–200 m, are given in Table F2. Also given in the table are the areas (in km^2) of each statistical region, and the estimated densities (kg/ha) and standing crop (tons) (from Williams, Tables 2, 3, 4 and 5). The latter two were estimated on the assumption that the trawl caught everything in its path, ignoring the effect (in different directions) of the escape of fish from the path of the net, and the shepherding by the bridles.

Table F2 - Estimates of standing stock of demersal fish from data of the Guinean Trawling Survey (GTS)

Statistical area	Area ('000 km^2)		Catch/hour(kg)	Density (kg/ha)		Standing stock ('000 tons)		
	15–50 m	50–200 m	15–200 m	15–50 m	50–200 m	15–50 m	50–200 m	Total
1	24,900	12,200	1,065	97	75	261	98	359
2	33,400	9,300	519	43	37	155	37	192
3	4,300	7,600	315	18	28	8	23	31
4	3,400	7,300	146	9	13	3	10	13
5	3,300	4,800	231	20	19	7	10	17
6	3,200	5,600	335	22	34	8	20	28
7	7,700	9,700	292	21	26	19	27	45
8	4,800	3,900	269	16	23	9	10	19
9	9,200	5,900	234	21	16	21	10	31
10	7,200	9,900	225	18	17	14	18	32
11	6,000	7,900	301	17	26	11	22	33
12	8,000	12,000	291	24	29	20	37	57
13	9,500	12,400	512	41	43	42	57	99
TOTAL	125,000	108,500	-	-	-	577	379	956

Many other trawl surveys of a greater or lesser extent have been made in the area, by both research and exploratory vessels (Salsen 1957; Postel 1949, Bonnet 1968, Karnicki 1968, Rasniewski 1968, von Brandt 1968, Klimaj 1968, Tixérant 1968, Domanevsky 1968). Most of these observations were not arranged in any systematic way, and the exploratory vessels particularly may have fished in the most promising localities in each area. Their catches, therefore, cannot easily be used to provide estimates of the mean abundance, though they do show the general distribution of fish, and the position of the richer fishing grounds.

More systematic surveys were made off Cameroun by Crosnier (1964), off Dahomey and Togo by Crosnier and Berret (1966), and off Nigeria by Longhurst (1965). In Longhurst's survey, the region covered in the Gulf of Guinea, from ca 9°E to 2°20'W, corresponds approximately to the GTS statistical areas 9 and 10, plus the eastern part of 8. Longhurst distinguished three communities (Sciaenid, on soft deposits above the thermocline, Sparids, on hard deposits above the thermocline, and on all deposits below this level, and the deep community, on the continental slope). He did not attempt to estimate absolute abundance from the catch rates, but used the relative catch rates to estimate the total potential trawl catches. The catches from the western part of the shallow zone, about 3,500 tons, were believed to be near the maximum. Extrapolating to the eastern area, and to the deeper water, using the ratio of the catch rates, gave an estimated total potential demersal catch of 14,500 tons.

Two comments may be made on this estimate. First, it is unlikely that the figure of 3,500 tons represents the maximum potential catch from the western shallow zone, even if no increase in catch could be achieved by any indiscriminate increase of fishing. As suggested by the Working Party, the use of a larger trawl mesh size (60-70 mm) is likely to increase long-term catches. Total catches might also be improved by greater concentration on the commercially less attractive species (e.g. Brachydeuterus). Second, the present rates of standing stocks for the heavily fished western shallow zone and the lightly exploited other areas will over-estimate the relative potential yields of the latter areas. These two effects act in opposite directions, to indeterminate extents. For the present purpose, an estimate of total demersal catches of 15,000 tons is probably as accurate as can be made.

This figure may be compared with the estimate, from the GTS, of a standing stock of demersal fish in Areas 9 and 10 of 63,000 tons. It has been estimated, in the introduction to this series of area reviews, that the potential yield may be roughly estimated as 0.5 x M x unfished standing stock, where M is the natural mortality coefficient. This is, in tropical waters, likely to be substantially higher than the values of 0.1-0.3 found in temperate waters. Using M = 0.4, and assuming the GTS estimate is of the unfished stock, this gives an estimate of potential catch equal to 0.5 x 0.4 x 63,000 = 12,600 tons. In fact the stocks in some parts of the GTS area have been reduced by fishing, so that this estimate is too low; making some correction for this, or assuming a slightly higher value of M gives remarkably good agreement with Longhurst's figures.

The GTS trawl catches, also, as already noted, included a variable and sometimes large proportion of pelagic fish (Sardinella, Caranx, etc.), but the gear used did not sample these effectively, and the only firm conclusion from the observations is that there are, as a minimum, certain times and places where these pelagic species are abundant. Studies towards more quantitative assessments of pelagic species, especially Sardinella are now being carried out by, inter alia, the group of United Nations Development Programme (Special Fund) projects in several west African countries. These species are already being exploited when available by purse-seiners from the Ivory Coast, and elsewhere.

For the demersal stocks, the above estimates of standing stock can be used to give a rough estimate of the potential catches. The ratio of standing stock : potential catch probably varies in the range 1 : 0.2, as above, for unfished stocks, to 1 : 0.5 or higher for heavily exploited stocks. The data of Table F2, for which as a rough measure half the shallow water, and all the deeper (over 50 m) water stocks are still lightly exploited, therefore give an estimate of total demersal potential in the region, south of Senegal, of 0.5 x 300 + 0.2 (300 + 400) = 290, say 300,000 tons.

5.5 Eggs and larvae

There are little quantitative data on the abundance of fish eggs or larvae in the region from which estimates of potential catch may be made. Various authors, e.g. Furnestin (1957), Kiliachenko (1968), have reported on catches, usually as presence or absence. The species occurring are much the same as in the catches with the addition of myctophids and others offshore. The work of Zei (1969) and Marchal (1966) shows that off Ghana and the Ivory Coast eggs and larvae of Anchoviella guineensis are very abundant, particularly towards the edge of the shelf. Probably the potential of these small anchovies is at least as high as sardinella.

5.6 Other evidence

The stomachs of some of the medium sized pelagic fish (bluefish, Lichia vadigo) off Cap Timiris, ca 19°N, were tightly filled with anchovy (Karnicki 1968, Rasniewski 1968), confirming the abundance of this species.

In tropical coastal waters, several authors (Longhurst 1957, 1966; Troadec 1969; Collignon 1960) have reported on the feeding of some of the major species. Fish are eaten by the larger croakers, but not in such quantity, or with some under-exploited species so dominant, as to suggest any great potential among these small prey species. The stomach contents do, however, suggest a large potential for penaeid shrimp and other small crustaceans, at least in some areas. These resources which are economically most important are discussed in detail in section R.

5.7 Oceanic resources

The resources of the open oceans, which are fairly similar in all parts of the world, are considered in detail in the separate section of the world review. However, the line between these resources and those of the continental shelf and slope is not precise. At present, the most important (and in many areas the only) oceanic resource is the tuna group. Important tuna fisheries are carried out in the Atlantic, both by long-line vessels, from Japan, Korea and Taiwan, and by surface fishing vessels - line bait and purse seine, from France, USA and several west African countries. Evidence of declining catch per unit effort shows that the stocks of yellowfin, at least, have been seriously affected by fishing (e.g. Le Guen and Wise 1967, FAO 1968).

An important, and as yet unexploited oceanic resource is the mid-water fauna. Studies of this fauna in the Gulf of Guinea have been reported by Voss (1969). Three main groups - cephalopods (especially *Ommastrephes pteropus*), fish (myctophids, hatchet fish, etc.), and crustaceans - were distinguished and all were very abundant. Voss noted that the lowest catch in the Gulf of Guinea was larger than nearly every catch taken with the same gear in those parts of the western Atlantic so far studied (Straits of Florida, Caribbean). The information is as yet far too scanty to attempt a quantitative estimate, but the potential is clearly very large, and the possibilities of economic exploitation, at least of the squid (e.g. by jigging), are not too remote. Good catches of squid (*Illex illecebrosus*) are often taken by trawlers on the upper part of the slope (100-300 m) all along the Gulf of Guinea.

6. DISCUSSION AND SUMMARY

In the previous sections, it was possible only to make reasonable quantitative estimates for the potentials of some of the demersal stocks, but these together account for only part of the total potential. In attempting to make an estimate of the total potential, some figures must be used for these other resources, especially the various pelagic resources.

Among the demersal stocks, the ones for which no estimate has been made, are those in the northern area (north of the GTS region), other than hake and sparids. These latter are now heavily fished, with a total potential, assuming ideal management, of 25-30,000 plus 200-250,000 = 225-280,000 tons. The proportion of other species (sole, croakers, dogfish, etc.) in Portuguese trawl landings from the old ICES area XI (off Mauritania) has increased from 25% in 1955 to over 60% in 1962/4 (Monteiro and Lima Dias 1968). This presumably reflects both the decline in hake and sparids, and, probably, an increased attention paid to these species by Portuguese fishermen as the preferred species declined. If the present relative contributions to the catches are the same as the relative potential yields, then the total potential yield of all demersal species may be estimated as ca 250,000 x 1/0.4 = 625,000 tons. This estimate is, of course, extremely rough, and also implicitly assumes, as seems reasonable, that among these various species the same opportunity exists for increasing catches by differential management as for the sparids and hakes.

In the northern area, trawlers also catch large quantities of cephalopods, and various medium sized semi-pelagic species (horse mackerel, etc.). Many of these are large vessels, and it is probable that in total fishing power the trawler fleets engaged in these fisheries are now about as large as those engaged in trawling for hake or sparids. The relative magnitudes of the fishing mortality coefficients caused in the various stocks will depend also on their vulnerability and distribution. The pelagic species may tend to suffer a lower mortality due to being dispersed through most of the water column; on the other hand their occurrence in dense shoals, which may be readily detected by modern sonar equipment, may tend to result in a higher fishing mortality than that caused on demersal fish by the same fleet of ships using bottom trawls.

These considerations suggest that the fishing mortality on these stocks may already be appreciable. There is as yet no clear evidence of falling catches per unit effort (Domanevsky 1968), though this may be due to the short period since heavy fishing started, and the often large variability in c.p.u.e. of pelagic fishes. As an estimate of the magnitude of the resource, it might be supposed that something of the order of 2-5 times the present catches of mackerel, horse mackerel, etc. may be taken, i.e. 200-500,000 tons. Similar arguments may be applied to the cephalopods, giving a range of potential catches of squid, cuttlefish and octopus of 300-650,000 tons over the shelf. Taking into account the oceanic squid, the total potential of cephalopods in the region would be much greater.

Quantitative estimates are even more difficult to make for the pelagic resources. In the north, catches of sardine off Morocco have been slightly over 100,000 tons for many years, with no evidence of the effect of fishing. Catches increased to 280,000 tons due to increased effort in 1966, but it is too early to see what effect this increase is having on the stock. The ACMRR/ICES Working Party found that it could make no useful statement regarding the state of the stock. For comparisons, the potential of the sardine (pilchard) stocks in the Northeast Atlantic (from Gibraltar to the English Channel) have been estimated in the appropriate section of this series as 400,000 tons. The sardines south of Gibraltar extend over a similar area, at an apparently comparable density, so the same figure of 400,000 tons might be used in default of better information, which is at least not inconsistent with the catch data.

For the other pelagic stocks, attempts at quantitative estimation are even more difficult, though they are probably of the same order of magnitude as the sardine, i.e. some hundreds of thousands of tons (but probably not millions of tons).

These estimates of potential are summarized in Table F3. The region has been considered in two areas, separated at 10°N. Clearly it would be preferable especially when comparing these estimates with primary production, etc., in view of the strong regional differences in primary production, to consider the potential in terms of much smaller areas. This is, however, impracticable until there are improved statistics available of catches by small statistical areas. Even in this table the data for some catches are not good enough to determine whether they fall into the northern or southern area. It is likely, for example, that some of the catches of sparids and other demersal catches included in the northern area should be included in the south; conversely all sardinella catches have been included in the south, though substantial catches (e.g. by Senegal) are taken north of 10°N.

Table F3 – Summary of the potential catches in the region (excluding tuna and crustaceans)

Total shelf area ('000 km^2)	North of 10°N 240		South of 10°N 240	
Catches ('000 tons)	Present (1966)	Potential	Present (1966)	Potential
Demersal: Hake	25	25–30		
Sparids	150	200–250		
Others	125	(400)		
TOTAL	300	650	170(a)	300
Pelagic: Sardines	280	(400)	70	(x100)
Anchovy	–	(400)		(x100)
Sardinella	30	(100?)		
Mackerel, horse-mackerel, etc.	100	200–500		
TOTAL	410	1,100–1,400	140(a)	(1,000?)
Cephalopods	150	300–650		
GRAND TOTAL	960(b)	2,100–2,700	310	(1,500?)
Catches per unit area (kg/ha)				
Demersal		25		12
Pelagic		50		(40)
TOTAL (including cephalopods)		(100)		(50)

Notes – (a) Dividing 180,000 tons of "unsorted and unspecified" between pelagic and demersal, in the ratio 1 : 2, since the larger number of demersal species makes specification and sorting more difficult

(b) Including 100,000 tons of "unsorted and unspecified"

The actual figures in this table should be treated with caution, though they represent what is the best approximation to potential that can be made at present.

They suggest a quite high potential per unit area, particularly in the northern area. Locally the potentials must be much higher, because the distribution is far from even. The biggest concentrations are in the upwelling areas, when the potential annual yields are probably in the region, of 200 kg/ha of all species. Elsewhere the potential is low, e.g. Collignon (1968) suggests a demersal potential of no more than 1 kg/ha, though this may be an under-estimate, perhaps not taking account of catches of fishermen other than from Morocco. For comparison, the primary production in the upwelling areas may be estimated as around 4 gC/m^2/day, which for 200 days of upwelling and some production outside the upwelling season, corresponds to an annual production of 1,000 gC/m^2. With an ecological efficiency of 10%, the production at later stages may be estimated as:

100 gC/m^2	herbivores (mostly zooplankton)
10 gC/m^2	1st stage carnivores
1 gC/m^2	2nd stage carnivores

If these last are commercial fish, then in terms of wet weight, their production is 10 g/m^2 or 100 kg/ha. Not all the production is harvestable by man; against this, the ecological efficiency may well be higher than 10%, and many commercial fish, especially the small pelagic species, come earlier in the food chain than second stage carnivores. Thus the potential of all species (200 kg/ha) in the upwelling areas appears not inconsistent with the data on primary production.

Practical possibilities for increased catches

The total potential of 3.5-5 million tons suggested in Table F3 is much higher than the present catches of 1.3 million tons. The prospects for an immediate increase in catch are not quite as promising as these figures suggest. Some of the demersal stocks in the north are heavily fished; most of the possible increase would come from more intense fishing of these stocks which are still lightly exploited (some sparids, elasmobranchs, croakers, etc.), many of which are of low economic value. This increase would have to be achieved without increasing the fishing on the more attractive stocks of hake and sparids, which would require some rather sophisticated level of international management. This is not likely in the immediate future. In the south increased catches can come, to a slight extent, from increased fishing on the more lightly exploited coastal stocks, but these are in the less productive areas, where catch rates are not economically attractive. Other opportunities occur in the deeper water (60-80 m), though some of the biggest potentials are of species, e.g. Brachydeuterus auritus, which are of less economic value. Shrimp trawling is also promising, though not considered in detail here.

The biggest potential is among the pelagic fish. It is suggested here that (apart from tuna, not here considered in detail), fishing on the larger fish (mackerels, horse mackerels, bluefish, etc.) could probably be increased. This conclusion is however rather tentative; those fisheries have been expanding rapidly, and the events of the next couple of years will probably see both sufficient data accumulated to determine the potential, and this potential approached (apart from the last fraction for which proper management is required), unless the potential is very much larger than seems likely. The same remarks probably apply to the cephalopods over the continental shelf; the feasibility of exploiting the oceanic squid is not established.

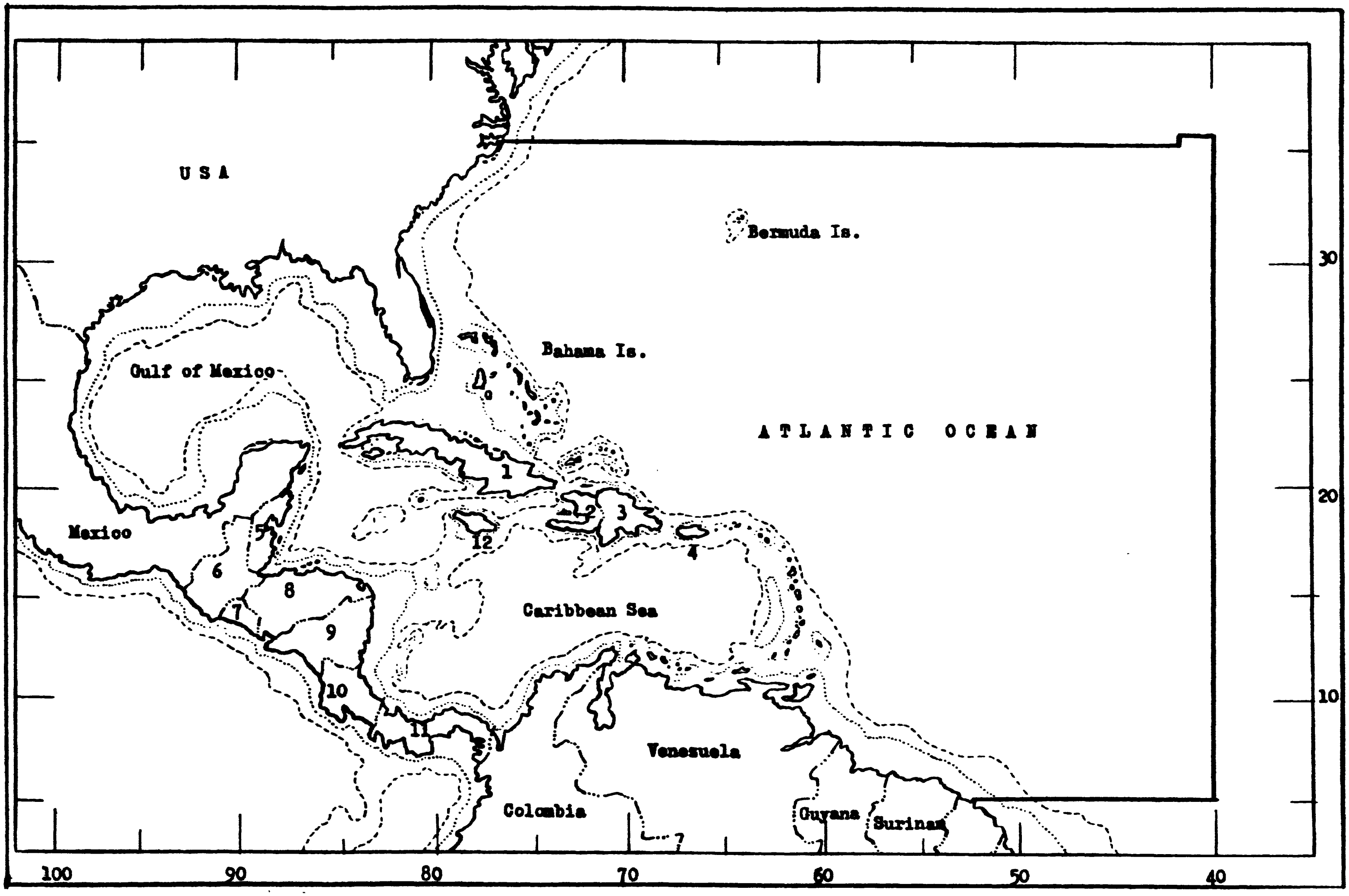
Among the smaller pelagic fish, increased fishing on both sardine and Sardinella seems feasible; the anchovies are untouched, but their exploitation, initially for fish meal, would seem to present no technical barrier, though detailed exploratory fishing is requested to determine whether this can be done at a low enough cost at the present world price of fish meal.

Requirements for future studies

The prime requirement is for better statistics; except for local fisheries, the place of capture is only known very roughly and about a quarter of the total catch is of unsorted and unspecified fish. The only data on effort and catch per unit extending for more than a handful of years are for the Portuguese trawl fishery in the north, and some of the local tropical trawl fisheries. For some countries the total catch is not known at all accurately, and some strengthening of the local statistical system is most desirable.

When statistical data are available for small areas, then it would be most useful to have correspondingly detailed data on the hydrography, especially upwelling, primary and secondary production, though in absence of catch data it would be difficult to use such information to improve the estimates of resource potential. For the secondary production - zooplankton and benthos - there is, however, at present not even broad regional estimates of production (and few of standing crop). Such estimates would greatly strengthen, and perhaps change, the rather weak arguments used here to check the estimates of potential from food-chain analyses.

Apart from statistics, the most urgent need is for a direct survey of the pelagic resources. A proposal for an international echo survey is contained in the ACMRR/ICES Working Party report. National surveys mainly for sardinella by several west African countries are being organised under the UNDP(SF) and are linked by a regional project.



G - WESTERN CENTRAL ATLANTIC

Depth contours at 200 and 2,000 m

Other countries:

Cuba
Haiti
Dominican Rep.
Puerto Rico
Brit. Honduras
Guatemala
El Salvador
Honduras
Nicaragua
Costa Rica
Panama
Jamaica

1. TOPOGRAPHY

As defined here the Western Central Atlantic area extends from 5°N lat. – approximately the northern extremity of Brasil – north to 35°N, the southern boundary of statistical area 6 of ICNAF (International Commission for North West Atlantic Fisheries) – eastwards to 42°N.

The region may be divided into five sub-areas – the US east coast; the Bahamas and the northeast coast of Cuba; the Gulf of Mexico; the Caribbean; and the Atlantic coasts of South America to the Brasilian border. For convenience the Atlantic coasts of the West Indian Islands east of the Windward Passage will be included with the Caribbean.

The US east coast within the present region extends some 1,100 km (600 n.mi), and has a fairly wide continental shelf – nearly 100 km (ca 50 n.mi). Along the coast there are a number of enclosed or semi-enclosed waters. Though the direct production from these waters has been excluded from this review, these estuarine areas, and the similar areas along the Gulf of Mexico coast are important breeding or nursery areas for several stocks of fish commercially exploited further offshore, e.g. shrimp (Kutkuhn 1966), menhaden (Reitjes and Pacheco 1966). The total area, excluding estuaries, down to the 200 m contour is about 110,000 km^2. Beyond the 200 m contour the slope is quite gentle, giving a wide expanse – the Blake Terrace – between 200 and 1,000 m, whose area is about equal to that within 200 m.

The Bahama Banks consist of a wide area of shallow water with low-lying islands; including also a rather narrow shelf along the north coast of Cuba, the total area within the 200 m (ca 100 fm) contour is 120,000 km^2.

In the Gulf of Mexico there are three areas of wide continental shelf – west of Florida, south of Texas and Lousiana and the Campeche Bank – which support rich fisheries. Along the rest of the Mexican coast the shelf is narrower; the total area of the Gulf is about 1.6 million km^2, of which a little under 600,000 km^2 is within 200 m.

The shelf area in the Caribbean is much smaller. The only large bank is the shallow Mosquito Bank off Nicaragua and Honduras, with a maximum width of ca 250 km and an area of ca 100,000 km^2; the other large expanse of shallow water is the Gulf of Maracaibo and Laguna de Maracaibo. The length of the coastline along Central and South America is nearly 5,000 km, and the arc of islands from Cuba to Trinidad extends for about 3,300 km. Except off Nicaragua, Honduras and the eastern part of Venezuela, the width of the shelf is no more than ca 20 km. The total area is 2.64 million km^2 of which about 10% (250,000 km^2) is shallower than 200 m, most of the shelf being in fact shallower than 100 m.

Outside the Caribbean the shelf off South America widens off Guyana and Surinam, with an average width, out to 200 m, of 90 km (50 n.mi), giving a total area within 200 m, of nearly 200,000 km^2.

The areas of shelf above have been taken somewhat arbitrarily as the 200 m contour. As noted above the extent of moderate depths (say, less than 1,000 m) is quite large off the US Atlantic coast. Elsewhere in the region the water deepens more rapidly beyond 200 m, so that the area of continental slope between 200 m and 1,000 m is no more than around 20–30% of that within 200 m.

2. HYDROGRAPHY

The main flow of surface water is clockwise through the region. The continuation of the South Equatorial Current (Guiana Current) flows west along the coasts of South America, and with the waters of the North Equatorial Current enters the Caribbean to form the Caribbean Current, flowing strongly westward. There is some wind-induced upwelling off the coasts of Venezuela and Colombia.

The waters of the Caribbean Current leave the Caribbean through the Yucatan Channel, and form a clockwise circulation in the eastern part of the Gulf of Mexico. The water leaves the Gulf of Mexico as the strong Florida Current, the beginning of the Gulf Stream system flowing northwards up the US east coast. The circulation in the western part of the Gulf of Mexico is confused.

3. PRIMARY PRODUCTION

Generally, production in the region is moderate to low, being highest in the coastal waters of the USA and in the limited upwelling area off Venezuela.

Average primary production is within the range 50-100 gC/m^2/year (Hela and Laevastu 1962, Fig. 37), but locally higher values occur, e.g. 1 gC/m^2/day, or ca 350 gC/m^2/year on the Venezuelan Shelf (Ballester 1968, Curt 1960, Hubert 1962), and up to 1,000 gC/m^2/year in coastal bays and mangrove areas, as opposed to as low as 20 gC/m^2/year offshore (Margalef 1968). Higher production has also been noted over the shallow waters off Nicaragua and Honduras (Hubert 1968).

4. ZOOPLANKTON

The distribution of zooplankton is similar to that of primary production. In the centre of the Gulf of Mexico and in the Caribbean standing crop (and presumably also production) is low. Higher values occur along the US Gulf coast, especially off the west coast of Florida, and off the mouth of the Mississippi. High densities of zooplankton also occur on Campeche Bank, and, in the Caribbean, towards the eastern end of the Venezuelan coast (Arnold 1958, Kromov 1965, 1965a, Bogorov et al. 1968). Quantitative information, particularly on production rather than standing stock, is lacking from many parts of the region. Owre and Foyo (1964) suggest that parts of the Caribbean are nursery areas for the stocks of adult copepods occurring in the Gulf of Mexico and Straits of Florida.

5. THE FISHERIES

5.1 Statistics

There is no compilation of international statistics for the region. National statistics exist in varying detail for all the countries in the region, but for none are the statistics entirely satisfactory. Thus the most extensive statistics are for the commercial fisheries of the USA but these do not include all the catches taken by the USA excluding two major categories: (i) sports catches, estimated as being as great or greater than the commercial catch for several important species - e.g. over half the estimated 3,000 tons catch of sea trout (*Cynoscion nebulosus*) (Tabb 1966); and (ii) incidental catches of fish, taken by shrimp trawlers, which are discarded at sea; these may be as much as 600,000 tons (Bullis and Carpenter 1968), to which should probably be added a corresponding quantity taken by Mexican and other shrimp vessels.

There is little fishing in the region by vessels from outside the region. There is some tuna fishing by Japan and other non-local countries, and trawling by USSR along the US east coast, and on a small scale by Japan off both North and South America.

Most fishing by countries within the region is done close to port with the exception of fishing by US vessels for shrimps, e.g. on the Campeche Bank. Thus the difficulties encountered in other regions in obtaining meaningful statistics from long-range vessels does not occur, and to a large extent the available statistics, mostly in terms of port of landing, can also for the present be used to give data on place of capture.

5.2 The fisheries

The most important fishery in the area is that for shrimp. This fishery originally centred in the Gulf of Mexico, and carried out mainly by US vessels, has now developed in other countries and areas, e.g. by Mexico, and off Venezuela and Guyana. The crustacean resources in the world as a whole are discussed in the relevant chapter, and the shrimp fisheries are not discussed further here.

The menhaden fishery of the USA is also very important in terms of volume, with peak catches of over 1 million tons in 1954-62, but the catch is used for the production of fish meal, so that the value is less than the large volume would suggest.

There is a very large number of other fisheries in the area, but each individually is rather small, generally with small boats, and rather simple gear, catching fish for local markets. This makes study of these fisheries, especially through analysis of statistics of catch and effort, somewhat difficult.

5.3 Stock assessments

Detailed assessments, with analysis of catch and effort statistics and of age composition data, including estimates of growth and mortality rates, do not seem to have been carried out for stocks in the

The most heavily exploited major fish stock is the menhaden (Brevoortia spp.). Total catches rose fairly steadily for several years up to 1959, and between then and 1962 remained around 1 million tons. Since then catches have declined to little over half a million tons in 1967. The cause of the decline is not entirely certain, but it seems to be associated with heavy fishing, and the stocks do not seem to sustain catches as large as 1 million tons. If the present decline can be arrested, catches might, with correct management, be sustained at around the 750,000 tons level.

Simpson (1968), analysing the Venezuelan sardine (Sardinella anchovia) fishery, found no clear change in size composition, or in catch per unit effort (though this might be a bad index of abundance), during a period when catches increased from 10,000 to 40,000 tons, suggesting that this resource is still lightly exploited.

For other stocks of fish even such rough estimates cannot be made, though it seems most stocks are greatly under-exploited.

5.4 Exploratory fishing

A considerable amount of exploratory fishing has been done in the area, particularly by the US Bureau of Commercial Fisheries, but also in the Caribbean by FAO/UNDP(SF) fishery development projects, and by the La Salle Foundation. As always it is somewhat difficult to use exploratory fishing to obtain quantitative estimates of standing stock, still less of potential. Estimation is easier for bottom fish than for pelagic fish, since a trawl can be a reasonably quantitative sampling instrument for fish that obligingly remain close to the bottom.

US Atlantic coast and Gulf of Mexico

The abundance of bottom fish off the US coast has been estimated by Bullis and Carpenter (1968) as 3 million tons, in the Gulf of Mexico and 1.5 million tons on the Atlantic coast south of Cape Hatteras. It is not clear whether these estimates are of abundance (standing stock) or of potential annual yield; if the latter they seem high - equivalent to 45 kg/ha of water less than 1,000 m deep off the east coast.

If the figures are of standing stock a rough estimate of potential may be obtained if it is assumed that the potential catch would be taken with a fishing mortality of 0.5, and at that fishing rate the stocks would be less than at present - about half the present level if they are virtually unexploited, as they probably are off the east coast. This gives estimates of potential of 380,000 tons off the US east coast and 750,000 tons in the Gulf of Mexico.

At present there is little fishing explicitly for bottom fish in the Gulf of Mexico, but large quantities - estimated as 600,000 tons - are taken, and discarded by shrimp trawlers. Therefore these fish stocks are far from being unexploited, and the figure of 750,000 tons is an under-estimate. Because the shrimp vessels use gear best adapted for shrimps, and work where shrimp (and not fish) are most abundant, the fishing mortality on shrimp is greater than that on bottom fish generally. Accepting that the shrimp (except those in deep water) are fully exploited (crustacean resources are discussed in more detail in another chapter), the fish are therefore probably still under-exploited, even though the optimum fishing mortality on fish is probably less than the optimum mortality on the generally shorter lived shrimp. The demersal potential in the Gulf is therefore probably in the range 1 - 1.5 million tons. This potential includes a wide range of species of very varied marked value. In many of the shallower grounds most fish will continue to be caught as by-catch in the shrimp fishery. Also in deeper water (100-500 m) the royal red shrimp appears to be the major resource in many areas (Bullis and Thompson 1965). At these depths, in the western Gulf, off southern Texas, shrimp are scarce, but hakes (Urophycis cerratus and Merluccius magrioculus) and snapper occur in commercial quantities.

Bullis and Carpenter (1968) studied the potential of the coastal pelagic fish, estimated as a total 5 million tons, 75% in the Gulf of Mexico. The most numerous group was believed to be anchovies, followed by thread herring (Opisthonema oglinum), neither of which are exploited. Menhaden are still common, but the stocks and catches have been declining. The fishing mortality on menhaden seems to be high, probably over 0.5, which would imply, with annual catches in the period 1963-7 varying in the range 830,000-540,000 tons, stocks of 1-1.5 million tons, and stocks of other species of 4-3.5 million tons. On the same arguments as used for the demersal stocks, the potential annual catches from the unexploited pelagic fish are 1-0.9 million tons (75% in the Gulf of Mexico and the rest off the US east coast), to which the potential of menhaden (750,000 tons) should be added, of which perhaps one third comes from the Gulf. This gives estimates of the total potential annual catch of pelagic fish as 1 million tons in the Gulf, and 750,000 tons off the US Atlantic coast.

Caribbean

In the Caribbean and along the Atlantic coast of South America, a number of surveys have been carried out (Whiteleather and Brown 1945, Mitchell and McConnell 1959, Ginés et al. 1968, Bullis and Thompson 1968, Rathjen 1968, Salnikov 1965). Extensive information is also available, as less formal publications, in the various internal reports of the FAO/UNDP(SF) Caribbean project. Because of the variety of gears used, a quantitative comparison between the results is difficult, but there is a fair degree of qualitative agreement.

Generally, the Caribbean appears less productive than the Gulf of Mexico, except for the eastern part of the South American coast. This part, and also the shelf off Atlantic coasts east of Trinidad, have given good trawl catches. The other areas not only appear less productive, but also contain a high proportion of rough ground - unsuitable for trawling. The prospects for commercial bottom fishing in these latter areas (off Central America and along the island chain) are mainly for handlining and similar methods; exploratory fishing results from these years are even less suitable for quantitative estimation of potential than data from trawling.

Handlining surveys by the FAO Caribbean project (Rathjen 1968) suggested that catches were higher in the cool season (January to June) than in the second half of the year. The areas off Nicaragua and from Hispaniola to the Leeward Islands gave higher catches than the Windward Islands, with Jamaica and Honduras being intermediate. It is likely that the main species - grouper, snapper, etc. - do not move far, and so form a number of small discrete stocks. Some of these, near to good markets, are probably heavily exploited. More certainly other areas are still under-exploited, but the factor by which the total catches might be increased cannot be accurately guessed - nor indeed are the present catches known with any great precision.

A range of values for the potential annual catches of larger bottom fish from the Caribbean, including off eastern Venezuela, which appears not unreasonable is 50,000 to 200,000 tons. This is equivalent to 2 to 10 kg/ha which is similar to the figures in other of the less productive parts of the world (e.g. Baltic 6, North Sea 15, Southeast Australia 2).

This range also is in reasonable agreement with the estimate for the potential of the commercially most promising group (the snappers and groupers) which was estimated by Carpenter and Nelson (1968) as 41,000 tons for the Caribbean.

The main fishery for pelagic fish (excluding tunas) is along the coast of Venezuela, where some 40,000 tons of sardine (Sardinella anchovia) and smaller quantitites of anchovy (Cetengraulis edentulus) and round herring (Opisthonema oglinum). The available information, which is most extensive for sardine, has been reviewed by Simpson et al. (1964) and Simpson (1968). Fishing is mainly by beach seines. Catches have increased with some fluctuations from 5,000 tons in 1946 to a peak of 44,000 tons in 1965. The figures of catch per set since 1957 show no clear trend though the catch per single set (Simpson 1968, Table 3) had some suggestion of a decrease. However, these figures are probably measures of school size and changes in abundance may change the number of schools, but not their average size so that total population abundance is poorly estimated. If anything, the figures of catch per set seem more likely to under-estimate changes in population abundance. While there is no evidence that the limit to the potential of sardine has been reached, it is probable that the opportunities for major expansion in catches of pelagic fish lie with other species. Bullis and Thompson (1968) saw few sardines in the OREGON operation off Venezuela and ascribed this to the fish being further inshore. Sardinella was not included in the large number of pelagic species attracted to lights off the Windward Islands (Bullis and Roithmayer 1968), but was one of the four genera used for tuna live bait by Rathjen (1968).

A rough figure of the potential of small pelagic fish can be obtained by assuming that, since there appears to be some decline in abundance, sardine catches off Venezuela could be doubled (80,000 tons) and that this accounts for between one-fifth and one-tenth of the total Caribbean potential, i.e. 400,000 to 800,000 tons.

A pelagic resource which is presently unexploited, but which offers a good chance for commercial development is the blackfin tuna (see chapter P).

South America

As noted above, the shelf between Trinidad and the Guyanas has been shown by several surveys to be comparatively rich, at least in the north-western part.

The most recent surveys of the area have been by the FAO/UNDP(SF) Caribbean project (Rathjen et al. 1969). These were concentrated in the central part, particularly off the mouth of the Surinam River. Catch rates were highest in this part - 450 kg/hour in summer, and 275 kg/hour in spring by the 80 ft CALAMAR - but also high in the other areas. The results confirmed earlier data that catches decreased greatly at depths beyond 20 fm (ca 35 m).

Estimates of the standing stock of demersal fish in the area have been prepared by W.F. Rathjen, based on the FAO/UNDP(SF) work, and previous surveys (see Table G1). The estimates are based on a working gap of the trawl of 12 m and a towing speed of 3 knots, and do not include any allowance for escape from the path of the trawl.

A very rough estimate of the potential yield, assuming a 50% escapement from the trawl, and a natural mortality of 0.6, and using the formula, potential = 0.5 x M x unexploited biomass, is then

1.5 x 0.5 x 0.6 x 350,000 = 160,000 tons

This suggests that, given the uncertainties in the data, the demersal potential is somewhere in the range 100-300,000 tons. This implies a yield per unit area of 5-15 kg/ha for the area as a whole, which appears perhaps rather low in view of the high catches in the shallow zone, but over half the total shelf area (out to 100 fm) is the less productive region beyond 20 fm.

Data on the pelagic resources are scarce. Off the Guyanas the FAO/UNDP vessels did not find any large mid-water traces on their echo sounder. The wind strengths were so high that no surface schools were seen, but clupeoids were common in the trawl, and in the stomachs of larger fish. The pelagic resources are thus probably as big as, or possibly rather larger, than the bottom fish resources, say in the region of 150-300,000 tons.

Bahamas

The area of shallow water round the Bahamas is notable for the variety of its species and the clarity of the water, rather than for its high production. Though the data are lacking, the productivity is probably less than in any of the other areas considered here. The fish potential might then be assumed to be toward the lower end of the range assumed for the Caribbean, i.e. 2-4 kg/ha of demersal fish, and 10-20 kg/ha pelagic.

Cephalopods

There seems no doubt that octopuses and squids form a large resource in the region, and one whose exploitation could probably be increased without too much difficulty (Voss 1960, 1968). Quantitative estimation of what the magnitude of the resource might be is much more difficult, especially since much of the most effective gear - pots for octopuses, jigging for squid - are even less quantitative than trawls.

In attempting to make an estimate, the following facts are relevant:

(i) squid are short lived, so that the potential yield is a large fraction of the unfished standing stock;

(ii) squid and octopus occur throughout the region, and at least locally are common, but apparently are not so strikingly abundant as in some other areas, e.g. Newfoundland;

(iii) present reported landings are 2,500 tons (Voss 1968); even adding unreported landings and discards, except in the shrimp fisheries, implies that present catches are probably less than 5,000 tons, plus by-catches in the shrimp fisheries, which might be quite a lot larger.

This is not sufficient for quantitative estimation. Guesses based on the somewhat more realistic estimates of fish potential in the region, and of cephalopod potential in other regions, suggest that the potential is more than 100,000 tons, possibly in the region 0.5 to 1 million tons, and probably not as much as 2 million tons.

Other evidence of potential: Eggs and larvae

There has been extensive plankton work in some parts of the area, especially off the US coast, but there are few detailed reports of catches of fish larvae.

Table G1 - Estimates of standing stock of demersal fish off the north-east coast of South America (provided by W.F. Rathjen from data of UNDP(SF) exploratory fishing)

	Region				
	Trinidad	Orinoco	Guyana	Surinam	French Guyana
Area (km^2)					
0 - 5 fm	3,200	5,200	8,300	6,900	9,000
5 - 20		3,300	17,100	17,700	11,200
20 - 100	17,200	8,300	20,900	34,400	36,700
TOTAL	20,400	16,800	46,300	59,000	56,900
Density (kg/ha)					
0 - 5 fm	23.5	(a)	(a)	(a)	(a)
5 - 20		5.4	28.7	48.3	19.1
20 - 100	7.4	(a)	1.9	2.6	3.8
Standing stock (tons)					
0 - 5 fm	7	3(b)	24(b)	34(b)	17(b)
5 - 20		2	52	86	21
20 - 100	13	7(c)	18(c)	29(c)	32(c)
TOTAL	20	12	94	149	70

Notes - Total area = 199,400, say 200,000 km^2

Total standing stock = 345,000, say 350,000 tons

(a) Not sampled

(b) Calculated using weight/ha of 5 - 20 fm interval

(c) Using densities of 8.7 kg/ha estimated from catches of R.V. CAPE ST. MARY

Off Virginia, in samples collected during all months of 1959, Massmann *et al.* (1961) found that 70% of all larvae collected were *Ammodytes americanus*. Flounders, butterfish (*Poronotus* spp.), sea robins (*Prionotus* spp.), anchovies (*Anchoa* spp.) and silverside (*Menidia menidia*) were the commonest other species, but none were particularly outstanding. This suggests that in this area, as in other parts of the North Atlantic, *Ammodytes* could provide large catches. Perhaps the resource potential could amount to the same as present catches in the North Sea, i.e. 100,000 tons annually.

In other parts of the area there are not sufficient data to modify the rough estimates of potential already made.

6. DISCUSSION AND SUMMARY

The estimates of potential derived in early sections are summarised in Table G2. All these estimates are at best rather rough, and the figures in brackets, which are largely based on comparison with other areas, are particularly likely to be inaccurate. However, the estimates are probably as good as can be provided with the present information, and are certainly good enough to show that the catches of fish from the area could be greatly increased if the technological and economic situation is favourable.

Resources which are substantial, but little exploited, include most of the small pelagic fish - excluding menhaden, and sardine off Venezuela - the demersal fish off the Atlantic coast of South America, and, probably, many of the local stocks of snapper and grouper in the Caribbean. Blackfin tuna are another valuable resource, but are considered in detail in the relevant chapter.

In nearly all stages of the analysis data have been inadequate. Some improvements of the estimates would therefore be achieved by better information at any stage, but certain pieces of information would be particularly valuable. These include:

Statistics

Better details of species caught, including data on fish discarded, especially in the shrimp fisheries. The preparation of a regional statistical bulletin, similar to those produced by ICNAF and ICES, and including details of area of capture, would be most valuable.

Environmental data

The present data, though sparse, are sufficient to identify the more productive parts of the area. For the immediate purpose of estimating potential, the supply of environmental data is less urgent than other matters, though such data are likely to be useful for other purposes, e.g. for understanding distribution of surface living fish.

Exploratory fishing

The available data, though extremely heterogeneous, show where are the major resources. Most of the methods used - fishing with lights, handlining, etc. - clearly give a non-quantitative estimates of total standing stock, or of total potential yield, and further survey work with these methods, though useful for assisting fishery development in delineating the most profitable grounds or seasons, is unlikely to increase greatly the precision of the estimates of potential. Bottom trawling in more quantitative, and further exploratory trawling, e.g. off the Atlantic coast of South America, would be valuable. Trawling is, however, not a suitable method for many stocks, e.g. pelagic fish and demersal fish on rough ground. New methods of survey - acoustic (sonar and echo sounder), and visual (e.g. satellite photography) (Pease and Drennan 1968) - promise better quantitative results at least for the off-bottom resources, and should be developed, and where suitable, applied to further survey work.

Stock assessments

Assessments by established methods for well established fisheries in the region, e.g. menhaden, some local snapper fisheries should be carried out.

Eggs and larvae

Existing data (publications and more particularly plankton collection) should be examined from the point of view of obtaining absolute measures of abundance of spawning stocks.

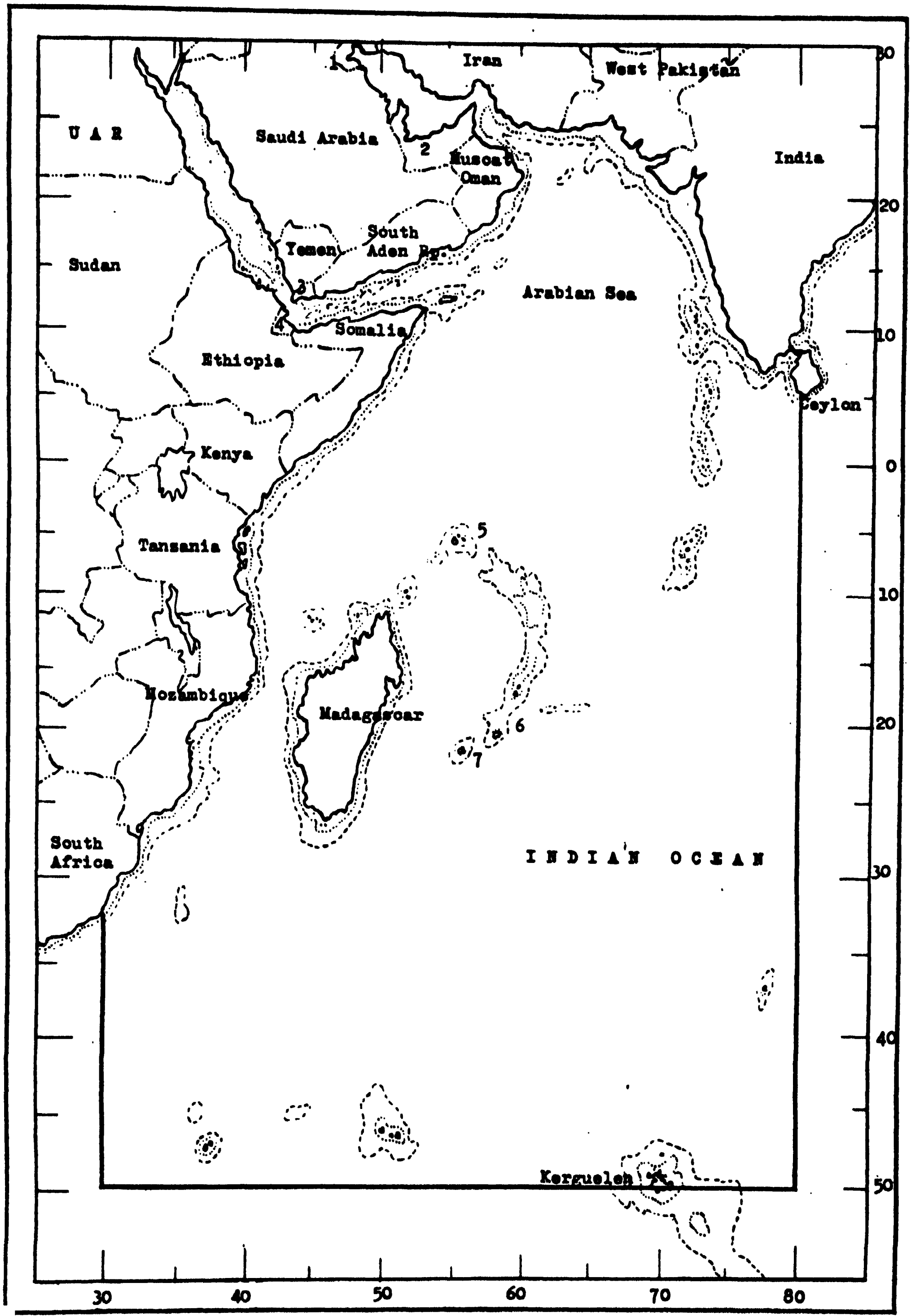
Table G2 – Summary estimates of potential ('000 tons, live weight)

	US East Coast	Bahamas NE Cuba	Gulf of Mexico	Caribbean	Atlantic S America	TOTAL
Shelf area ('000 km^2) (to 200 m)	200	120	600	250	200	
Potential ('000 tons)						
Demersal	380	(25–50)	1,000–1,500	50–200	(100–300)	1,500–2,500
Pelagic	850(a)	(120–240)	1,000	(400–800)	(100–300)	2,570–3,190
TOTAL	1,200	150–300	1,700–2,400	450–1,000	(600–1,200)	4,100–6,100
Crustacean (b)						260
Squid						?
Myctophids						?
Potential per unit area above 200 m (kg/ha)						
Demersal	22	2–4	12–23	2–8	15–30	
Pelagic	35	10–20	16	16–32	15–30	
TOTAL	60	12–24	30–40	18–40	30–60	

Notes – (a) Including *Ammodytes*

(b) Crustaceans, molluscs and tuna are considered in the relevant chapters

Brackets denote estimation

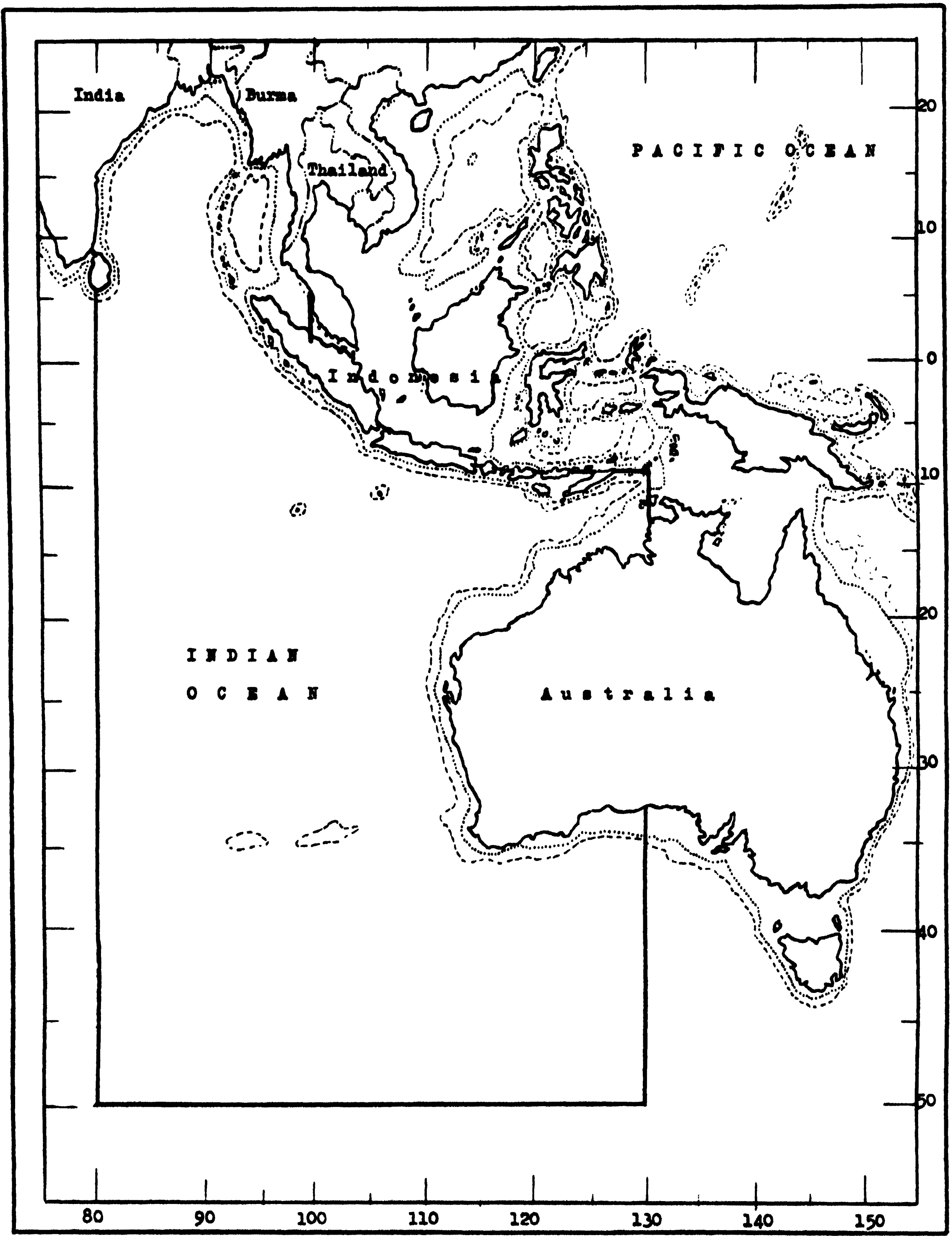


- WESTERN INDIAN OCEAN

Other countries/islands:

Kuwait
Trucial States
Aden
Eritrea
Seychelles
Mauritius
Reunion

Depth contours at 200 and 2.000 m



H - EASTERN INDIAN OCEAN

Depth contours at 200 and 2,000 m

1. TOPOGRAPHY

The present chapter includes the coastal waters of the Indian Ocean and adjacent seas from Cape Agulhas, South Africa, to the Thailand-Malaysia border (ca 6.4°N lat., 100.1°E long.), the southern coasts of Indonesian islands bordering the Indian Ocean, and the west coast of Australia. Also included are the Red Sea, Persian Gulf, and the banks and waters surrounding the islands of the Indian Ocean. (Some of these boundaries, particularly round Australia, which have been used for past statistical tabulation and in this study, are likely to be amended for future statistics.)

The areas of the shelf and slope regions to the 1,000 m depth contour are given in Table H1 adapted from the data of Moiseev (1969).

Table H1 - Areas of shelf and upper continental slope on the Indian Ocean (from Moiseev (1969)('000 km^2))

Area	Shelf (0-200 m)		Upper Slope (200-1,000 m)	
East Africa	390		440	
South Africa (east of 30°E)		140		100
Mozambique		120)		180
Tanzania-Kenya		10)		160
Somalia		120)		
Arabian Sea	400		300	
Arabia and Gulf of Aden		80		140
India-Pakistan West Coast		320		160
Bay of Bengal	610		240	
India-Pakistan East Coast		190		140
Burma		250		40
Thailand-Malaysia		170		60
Indonesia	130		100	
Western Australia	380		90	
South Australian Coast (to 130°E)	260		90	
Red Sea	180		200	
Persian Gulf	240		-	
Madagascar	210		100	
Oceanic Islands	(200)		(100)	
TOTAL	3,000		1,600	

Note - Brackets denote approximation

Except for the relatively wide shelf zones in the eastern sector of the Arabian Sea, the eastern sector of the Bay of Bengal and the north-northwest coast of Australia, the continental shelf of much of the Indian Ocean and adjacent seas is extremely narrow and in places precipitous. Along the East African coast, the 200 m contour line is in many places less than 4 km from shore. In addition to the narrow shelf, coral reefs and coral outcroppings are found throughout the area, especially along the African coast.

The Red Sea extends in a general northwest-southeast direction for about 2,200 km and has a maximum width of 352 km in the vicinity of Massawa in the south. The average depth of the Red Sea is about 700 m, with some deep pockets exceeding 2,000 m. The northern sector has some shallow areas which are trawlable, e.g. in the Gulf of Suez, but for the most part the northern waters are considered to be too deep for trawling. The continental shelf widens in the central and southern Red Sea and in some areas in the south sector the shelf extends for more than 11 km offshore.

The Persian Gulf is a relatively small body of a water covering approximately 239,000 km^2 with an average depth of 35 m and a maximum depth of 150 m. An indication of the extent of shallow areas is indicated in the northern sector, off Iraq, where the depth is only 8 fm 46 km offshore.

2. HYDROGRAPHY

2.1 Currents

The striking feature of the surface currents in the Indian Ocean is the reversal occurring in the northern parts - Arabian Sea and Bay of Bengal - following the changes in the wind system with the monsoons. This has no close parallel in other oceans.

The current system in the southern Indian Ocean is similar to those in the Atlantic and Pacific. The South Equatorial Current flows westward at around 10°S, dividing as it approaches the African coast. The southward flowing arm branches each side of Madagascar, uniting to form the Agulhas Current. The West Wind Drift, and a weak and rather confused northward flowing current off Western Australia, completes the anti-clockwise gyre in the southern Indian Ocean.

In the northern Indian Ocean, during the southwest monsoon (April-September) the Somali Current flows northwards along the coast of Africa as a swift and narrow current; speeds as high as 7 knots have been reported (Swallow 1965). The width of the Somali Current at the Equator has been estimated at 9 km and the current widens to about 74 km farther north. At the height of development, the Somali Current reaches as far north as 12°N lat.;however, most of the water leaves the coast and flows in an easterly direction as the Monsoon Current south of 10°N lat.

In the Gulf of Aden, the flow of the surface current is from the Gulf into the Arabian Sea from June through August. Along South Arabia, the currents are weak and move in an east and northeasterly direction; along India, the flow is in general southerly.

In the Bay of Bengal, the flow pattern during the southwest monsoon period is generally northeast. Upon reaching the continental coast, most of this water turns southward and flows along the continental shelf. South of Sumatra, the current flows southeasterly along the coast of Sumatra and merges with southeast Asian water flowing into the Indian Ocean through the Timor Sea. These waters form the basis of the South Equatorial Current in the Indian Ocean. It should be noted that during some months there is a southerly flow of water along the east coast of India.

The northeast monsoon (October-March) brings about considerable changes in the circulatory pattern, especially in the northern seas. The Somali Current reverses direction and flows southerly from December through February. Surface current flow in the Gulf of Aden is from the Arabian Sea into the Gulf. For much of the northern sector of the Arabian Sea, the surface currents are weak and variable with no one direction generally prevailing. For a brief period, November-December, a weak current flows northward along the coast of India. In the Bay of Bengal, a cyclonic circulation occupies the entire Bay in February; however, this pattern does not prevail during the entire northeast monsoon period.

2.2 Upwelling

Zones of upwelling have been discovered in various localities throughout the area under consideration. In the Arabian Sea, one of the most pronounced zones of upwelling occurs in waters off South Arabia from Kuria Muria Bay to Ras al Hadd during the southwest monsoon. The upwelling appears to be seasonal; there is no evidence that upwelling occurs during the northeast monsoon.

In the Arabian Sea, a second pronounced area of upwelling occurs off northern Somalia within 40 km of the coast (Swallow 1965). Although the cold water is rich in nutrients, there is very little evidence of a high level of biological activity. A high standing crop of plankton is evident only in the northern part of the cold water area, in the vicinity of Cape Guardafui.

In the Bay of Bengal, La Fond (1958) reported areas of upwelling along the east coast of India during the southwest monsoon. Wyrtki (1961) indicated that some upwelling seems to develop in the Andaman Sea during the northeast monsoon.

Possibly the most important upwelling occurs in the eastern Indian Ocean south of Java. Wyrtki (1962) estimated the extent of the area of upwelling as 400 km wide and 1,200 km long. He computed the rate of flow of water as 2.4 million m^3/sec.

Another area of upwelling in the eastern Indian Ocean occurs off the northwest coast of Australia. Rochford (1962) showed that in the area of upwelling the inorganic phosphate values in the surface waters measured 0.3 μg at/l, values considerably higher than the 0.1 μg at/l for adjacent waters.

A general review of the upwelling areas of the world, and their biological productivity has been given by Cushing (1969).

3. PRIMARY PRODUCTION

Except for some areas along the west coast of India, eastern south Africa (Burchall 1968), and the west coast of Australia, very little published information is available on primary production of coastal waters in the Indian Ocean. Undoubtedly, efforts during the International Indian Ocean Expedition (IIOE) have added considerable amounts of biological and oceanographic data to the fund of information of the Indian Ocean; however, data on phytoplankton and zooplankton are still inadequate for proper evaluation of the total annual standing crop in time and space.

Ryther and Menzel (1965) provided some indication of the richness of the waters off South Arabia. On two stations occupied off the Gulf of Oman, they obtained values of 5.7 and 6.4 gC/m^2/day, values which compare favourably with waters off Peru. As shown in the Atlas of the Arabian Sea for Fishery Oceanography (Wooster et al. 1967), data on primary production in the Arabian Sea are sparse and inadequate to provide anything but a general indication of the production of the northern Arabian Sea. For the June-July-August period data, only five C^{14} observations were available to Wooster et al. (1967). Undoubtedly, more measurements have since been made; to date these data have not been made available. It is doubtful, however, that all of the observations made to date add to a large total.

Subrahmanyan (1959) provides the only estimate of the phytoplankton production for the entire west coast of India. He considered an area 1,200 mi (2,000 km) long (coastline of west India) by 50 mi (90 km) wide and estimated the production to be 1.813 million tons.

4. ZOOPLANKTON

Much of the zooplankton data collected during IIOE are still being processed and analysed. It is doubtful, however, that these data are sufficient to give more than a generalised view of the zooplankton distribution in coastal waters of the Indian Ocean. Tranter (1962) estimated the average standing crop of zooplankton from the Australian continental shelf waters as 100 mg/m^3 and less than 50 mg/m^3 for the open ocean. He further indicated that the waters of the upwelling area off northwest Australia were as rich as waters over the continental shelf.

The standing crop in the Indian Ocean was included in the world summary given by Bogorov et al. (1968). These studies show few rich areas in the Indian Ocean. A density of 200 mg/m^3, found in most of the fertile areas of the North Atlantic and North Pacific, and a large part of the upwelling areas off the western Americas and west Africa, is reached in the Indian Ocean only on a narrow band along the western Indian peninsula, and off southern Arabia. The general level in the coastal areas is 100-200 mg/m^3.

5. FISH STOCK AND FISHERIES

The marine catch from the Indian Ocean and adjacent seas is about 2 million metric tons (see Appendix Table H1). On the basis of yield per unit surface area, the Indian Ocean yield was only about 1/5 of the Atlantic and the Pacific yields (Shomura et al. 1967). Much of this relatively low yield can be attributed to the low level of fishing effort, using for the most part primitive gear of the type employed in subsistence fishing. Fishing in many parts of the coastal waters of the Indian Ocean, especially along Africa, is still carried out in non-motorised boats with simple gear. Large-scale fishing with large vessels is confined to (1) the high seas longlining for tunas and billfishes conducted by fishermen of Japan, USSR, China (Taiwan) and more recently Korea, and (2) bottom trawling and purse seining, in the Gulf of Aden and waters off south Arabia, by USSR, southern European and Japanese fishing vessels, though this has been effectively halted since the closure of the Suez Canal in 1967.

5.1 The fisheries

(a) East African Coastal Region (South Africa, Mozambique, Tanzania, Kenya)

Much of the fishing carried out along the east African coastline is of a subsistence type and confined to the immediate coastal waters. Presently, the fish species exploited include Sardinella, seerfishes, sharks, and various demersal and pelagic fishes which are caught throughout the area. Recent attempts to catch sardines and other small schooling pelagic fish with purse seines and stick-held dipnets (bouke-ami) using light in Tanzania waters have met with fair success. Catches in the purse seine fishery have averaged 1.8 tons/boat/night during the period 1963-6.

Very little experimental bottom trawling has been conducted in this area. For the most part, the results have been negative and indicate that trawl gear cannot increase the fish yield in east African waters. The lack of success has been attributed to the extensive coral outcroppings in this area and to the narrowness of the continental shelf. Trawling, however, should not be ruled out, since most of the trawling was done by large vessels working in shallow depths. It is possible that successful results could be achieved with small trawlers. A similar situation existed in the Gulf of Thailand, where only after the introduction of offshore trawling with small boats and small nets did the fishery flourish (Tiews 1966).

(b) Arabian Sea

Very little fishing is carried out in western Arabian Sea, more because of the lack of markets for a local fishery than through lack of fish. A rough estimate of 100,000 tons has been made for the catch of sardinella in Muscat and Oman, caught close along the shore. Recently a number of long range trawlers from Greece, USSR and Japan have worked off the southern coast of Arabia and northeast coast of Somalia, reporting catches of some 30 tons/day; the number of those ships has decreased since the Suez Canal was closed.

Important shrimp fisheries, discussed in detail in another chapter, have developed in the Persian Gulf, and along the Pakistan and Indian west coast.

The Indian west coast also supports important traditional fisheries, particularly the seasonal fishery for sardinella and mackerel. This fishery, and the other fisheries for shrimp and bottom fish, are all carried out by medium to small vessels with a limited radius of action.

(c) Bay of Bengal

In the northern parts of the Bay of Bengal the fishing season begins in November and ends in February, principally because of the rough weather brought on by the southwest monsoon. The fishing gear consists primarily of drift nets, set nets, stake nets, and longlines. Trawling for demersal fish is conducted throughout the area. The most important fishery in East Pakistan is for the threadfin (Polynemus indicus).

The fishery resources along the Indian Ocean coast of Thailand were until recently virtually untapped. Marketing problems, primarily resulting from the long distances from population centres, and the emphasis on trawling in the Gulf of Thailand have until recently retarded the development of the west coast fisheries.

The Thai fishery in the area has expanded very rapidly since 1966, many fishing boats being transferred from the east coast, and newer and larger boats (20-25 m) have been built. 1967 catches of mackerel (Rastrelliger) by Thailand were around 45,000 tons. The longer established Malay fishery in the Strait of Malacca is at present at around the same level.

(d) Indonesia

The estimated catches for the southern coasts of the Indonesian islands bordering the Indian Ocean are provided in Appendix Table H1. The catch for Indonesia was obtained by taking 25% of the total Indonesian marine catch. The basis for this separation is that the available literature, which is extremely limited, indicates that most of the fishing takes place in the northern waters. The important species include sardines, anchovies (Stolephorus spp.), mackerel, mackerel scad, and skipjack tuna. One of the most important fisheries for sardine occurs in the strait between east Java and Bali. All the fishing is carried out by small boats, usually close to shore and with simple equipment.

(e) Western Australia

The catches of fish (in the narrow sense) round western Australia are very small. Some catches of Australian salmon (Arripis trutta) are taken inshore along the southwest coast, and local fishermen take a variety of other species in small quantities. Japanese trawlers have worked occasionally off the northwest coast. The large fisheries are for crustaceans, which are discussed in the relevant chapter. The stocks of crayfish (spiny lobster, Panulirus cygnus) seem fully exploited in the present areas, but offer potential for expansion from Shark Bay and Exmouth Gulf northwards. The shrimp fishery has been expanding steadily northwards to Shark Bay and Exmouth Gulf.

(f) Red Sea

Presently the major fisheries in the Red Sea are the sardine fisheries in the northern part of the Red Sea, and along the Ethiopian coastline, and the bottom trawl fishery in the southern waters of the Red Sea. Ben Tuvia (MS), who provides the most comprehensive review of the fisheries in the Red Sea, indicated that the northern waters did not appear to be productive enough to support much more than is being taken at present. To date, efforts to harvest tunas in commercial quantities with purse seine, longline, and gillnets have met with little success (Ben-Yami 1964). Also, the purse seine and light method used successfully to catch sardines and other small pelagic fishes in other areas has not been very successful in the Red Sea.

(g) Islands and banks

With some exceptions, e.g. the trawl fishery of Ceylon and a small tuna fishery operating from Minicoy Islands in the Maldive Island Chain, most of the island fisheries have been of the subsistence type using predominantly handlines, set nets, and traps, catching a variety of species, mainly bottom living species. In Madagascar, a shrimp fishery for export has recently developed.

5.2 Statistics

Basic catch and effort statistics are virtually non-existent for much of the Indian Ocean. In many areas, some subsistence fishing undoubtedly goes unreported, thereby under-estimating the reported total catches. In other areas, e.g. Burma, the reported catch has not changed over the years, a condition highly improbable and one which indicates a lack of complete data.

The fisheries of western Australia, especially the crustacean fisheries, have probably the best statistics; fair statistics are also available for the fisheries of India. Long-range fishing, except for tuna, is still very uncommon, so that information on place of landing also gives good information on place of capture.

5.3 Stock assessments

(a) Demersal fish

The Wadge Bank off the southern tip of India, with an area of 4,000 n.mi^2 (13,500 km^2) is one of the few areas where even approximate assessments can be made. It has been fished for many years by trawlers from Ceylon, and there exist good records of these operations, which have been going on, with interruptions, for some 50 years (Mendis 1967). It has also been fished by Indian vessels from Tamil Nadu and Kerala coasts, but statistics of these catches are not available.

Until 1966, only two or three trawlers operated, but recently five new stern trawlers have been added to the fleet. The total catch in 1967 was 2,000 tons, compared with peak production in early years of under 1,500 tons. (These figures exclude quantities of low valued fish rejected at sea, estimated by Mendis as some 20%).

Sivalingam (1966, MS) has studied the relation between the amount of fishing and the catch per unit effort, considering separately three groups of species; the larger resident species (snappers, etc.), smaller resident species, and migrants (mainly carangids), the last being only caught in quantity during the southwest monsoon. For the big fish, he noted a decline in both catch per unit effort and average size when fishing was increasing, and deduced that the maximum sustained yield of these species was around 500 tons. The catch per unit effort of smaller species showed no decline, probably because of a shorter life-span, less intense fishing, and a possible switch in fishing attention onto these as the larger species declined. Though in the period studied the smaller species never totalled more than half the larger species, it is probable that their potential is as large. The heavily exploited area is only a fraction of the total bank - estimated by Sivalingam (MS) as 1,250 n.mi^2 out of the total of 4,000 n.mi^2. The density on the unexploited areas is presumably less, but even if it is only half that of the exploited areas the total potential in the former areas would be slightly greater. Altogether, making some allowance for migration between exploited and unexploited areas, the total annual potential of the two first groups of species on the whole bank may be rather more than five times the potential of big fish in the exploited parts, say 2,500-3,500 tons.

The most recent information of the species composition of the trawl catch has been given by Fernando (in press); 66% were resident species, the rest being migrants, appearing only in the southwest monsoon, nearly equally divided between carangids, elasmobranchs, and catfish (Netuma thalassinus). Since the migrants appear in the catches for half the year only, it is a reasonable supposition that the ratio of potential to present catch is twice that for resident species. This implies a total potential of 5-7,000 tons.

Two independent estimates of the fish stocks have been made. Mendis (1965) estimated the total standing stock, from trawl catches, and the area swept by the trawl, as 18.5 million lb, or 8,500 tons. Using the formula, potential = 0.5 x unfished standing stock x natural mortality, this would be consistent with the above estimate if natural mortality were 1.2-1.6; these seem rather high, but Mendis' data referred to a period of moderately heavy exploitation, when the standing stock would be less than in the unfished condition. The two estimates are, therefore, in fair agreement.

Mendis (1967) also obtained estimates based on the primary production of the potential fish production of 54 million lb (25,000 tons) of all species of fish, 65% of which would be good quality. This estimate is very sensitive to the precise figure used for the efficiency of transfer from one trophic level to another, as well as to the position of the fish in the food chain. It, therefore, agrees moderately well with the other estimates, but suggests that the upper figure (7,000 tons) is perhaps the more likely. This implies a potential of bottom fish of about 5 kg/ha.

A rough assessment can also be made for the area off Karachi. Zupanovic (FAO internal reports) has noted that locally fishing appears very intense, and the local stocks are probably fully exploited. This applies only to depths out to about 15 fm (30 m) and to the area close to Karachi, i.e. to a strip about 20-25 n.mi wide, and perhaps 80-100 n.mi long, with an area of ca 7,000 km^2. Landings of demersal fish at Karachi averaged around 20,000 tons in 1965-7, presumably mostly from the heavily fished area, equivalent to a yield of a little under 30 kg/ha. Assuming that this could be increased somewhat by better management, the potential might be as much as 40 kg/ha.

Exploratory fishing: Ocean islands and banks

A quantitative survey of the ocean banks, e.g. by trawling, is made difficult by the rough ground. Wheeler (1953) lost three trawls without catching a fish, and based his estimates of standing stock on line fishing. His technique was to allow the ship to drift sideways, thus effectively sweeping an area equal to the length of the drift times the width, taken as 40 ft, the distance apart of the outside lines. Clearly this could easily result in over-estimates if fish are attracted in from outside the path (especially likely for sharks), or an under-estimate if not all the fish in the path take the bait. In particular, the smaller fish will be greatly under-estimated. However, the data do provide a first estimate of the standing stock.

These estimates, derived from the data of Wheeler (1953, section VI) are given in Table H2. The totals differ from his totals of 1.1 million tons of fish, and 0.8 million tons of sharks because there appears to be an arithmetical mistake in his estimate for the Sava de Malha corpus. Making allowance for the other banks and islands, e.g. the Maldives, not included in Wheeler's study, suggests a total standing crop of about 0.5 million tons of larger bottom fish, and sharks.

For sharks, the above figures are more likely to be an over-estimate than an under-estimate of standing crop; also, due to the low fecundity and long life of sharks the potential yield is probably a small fraction of the unexploited standing stock. Probably the potential yield on the banks is no more than around 100,000 tons, unless there is continual immigration from the open oceans.

For the other fish (Lutianus spp., Lethrinus spp., etc.), the standing stock is less likely to be over-estimated, and the potential is likely to be a bigger fraction of it. Little is known of the average life-span of these fishes. There is some general experience with reef fisheries that initially high catch rates cannot be maintained, which suggests a low rate of replacement, and presumably also of mortality. However, the natural mortality in tropical waters, even of relatively long-lived fish, may be higher than is common in temperate waters, so that the potential may be half to a quarter of the unexploited standing crop. Allowing for some under-estimation of this latter, the potential of the larger bottom fish may be around half the estimated standing crop, in Table H2, i.e. 0.25 million tons (the figures of 9.8 and 2.8 million tons given by Wheeler appear to be due to a confusion between total quantity and quantity per mi^2, on the Soudan Bank). This is equivalent to about 12 tons per mi^2 or 3.5 tons per km^2. This is about a little greater than the existing yields estimated by Wheeler for the waters around Mauritius (10 tons/mi^2), which were believed to be over-exploited.

No estimate is possible of the potential of the smaller reef fishes, not vulnerable to the type of line fishing used by Wheeler.

Table H2 - Estimates of standing crop of large fishes and sharks around the islands and banks of the western Indian Ocean (derived from Wheeler 1953)

	Fishable area ($n.mi^2$)	Tons/mi^2		Total standing crop (tons)	
		Fish	Sharks	Fish	Sharks
Chagos					
Speakers Bank	216	39.4	48.3	8,510	10,432
Peros Banhos	117	31.2	4.5	3,650	526
Great Chagos	2,000	41.3	65.3	82,600	130,600
Pitt Bank	100	5.6	53.1	560	3,310
TOTAL	2,433			95,320	144,868
Oceanic Banks					
Hawkins Bank	70	(1)1/	(30)1/	70	2,100
Soudan Bank	240	8.5	5	2,040	1,200
Nazareth Bank, south	900	8.5	6.9	7,650	6,210
Nazareth Bank	3,100	22.3	7.5	69,130	23,250
Saya de Malha, coccyx	100	2.1	62	210	6,210
" " " corpus	4,450	26.9	18.3	119,705	81,435
" " " cervix	700	48.4	65	33,880	45,500
" " " caput	150	26	67.3	3,900	10,095
Fortune Bank	126	5.2	84.3	655	10,622
Constant Bank	200	8.8	41.5	1,760	8,300
Amivantes	640	26.6	23.7	17,024	15,168
TOTAL	10,676			256,024	210,090
Seychelles	3,000	15.5	18.7	46,500	56,100
TOTAL ($n.mi^2$)	16,109	24.7	25.5	397,844	411,058
TOTAL (km^2)	55,300	7.2	7.4		

Note - 1/ Estimated from catch per man

Coastal trawling

In the western Indian Ocean (off the Arabian and African coasts) little exploratory fishery has been done. Some experimental trawling has been done by Kenya and by the East African Marine Fisheries Research Organisation. Catches of teleosts have been light, and this may be attributable to the clear water, and the fact that most of the demersal fish live near the coral, where trawls cannot be used.

In the northern and eastern part of the area - in the arc from West Pakistan around India to Malaysia - there has been during the last decade a large amount of exploratory and research trawling, much of which, and also a summary of earlier surveys, was reported to the 1968 IPFC Symposium on Demersal Resources (Rao in press). These operations were carried out by a variety of different vessels, using a wide range of gears, and operating in different ways - on a semi-commercial basis, with fishing concentrated on the best areas, or on a predetermined grid, etc. Too much, therefore, should not be made of these data in the way of detailed comparison between areas, though they can be used to provide a rough guide to the potential, particularly the species composition, and the depth distribution.

Exploratory fishing off West Pakistan has been described by Hussain *et al.* (in press); these operations, by M.F.V. MACHHERA (52 tons, 120 HP engine) were restricted to waters within 70 mi. In some areas, e.g. off Karachi, catch rates have been falling during the period of the surveys (1960-7), and this decrease appears to be due to the heavy fishing there. The average catch per hour was 44 kg - or 0.37 kg/HP/hour. Of this a proportion 10-30% was inedible or unmarketable fish which were discarded at sea.

Further exploratory fishing in the offshore waters of West Pakistan (outside 12 mi, down to 1,000 m) was carried out in the early part of 1969 by USSR vessels, in collaboration with Pakistan. In the western part, to the Ras Malan Cape the narrow shelf and steep continental shelf offered no suitable trawling grounds. In the other part, off Karachi and the mouth of the Indus, some good catches were taken. Between 25 m and about 100 m catches by the vessels (RTM and SRTM type) were around 1.0-1.5 tons/hour or about 0.2-0.3 kg/HP/hour. Beyond 100 m catches tended to decrease, becoming small at 300 m, and the limited number of hauls between 800 m and 1,000 m caught virtually nothing.

The results of the exploratory fishing by Government of India vessels between 23°10'N and 15°N has been summarised by Rao *et al.* (in press). The larger vessels (ca 300 BHP, 120 GRT) averaged 194-387 kg/hour in different latitudinal zones, the lowest being at 18°N, south of Bombay, and catches increasing to the north and south, being approximately equal at 22°N (365 kg/hour) and 15°N (387 kg/hour). Some, at least, of the differences may be due to the heavier fishing around Bombay.

In terms of depth, best catches were between 50 and 60 m (365 kg/hour), decreasing to around 100 kg/hour both in deeper water (80-90 m) - though few hauls were made at this depth - and in shallow water (<10 m) - though the smaller vessels may have made relatively more hauls on these depths. There appeared to be a tendency for the optimum depth to increase from south to north.

Slightly different variations of catch rates with depth for catches by commercial bull-trawlers from Bombay were noted by Rao (1969). Most fishing (ca 78%) was done between 25 and 45 m, with catches around 900 kg/hour. About the same weight per hour was caught in shallow water, but were less valuable species - nearly half of those in the 16-20 m zone were elasmobranchs. Catches in deeper water decreased to only 420 kg/hour in 71-75 m, the deepest zone fished.

The seasonal range in catch rates was relatively small, perhaps surprisingly so in view of the big environmental changes due to the monsoon; the best month was August (310 kg/hour) and the worst January (166 kg/hour).

Trawling in the south-western region (from Cape Cormorin to 15°N) has been described by Rao (1967, 1969). The area includes some rich shrimp grounds, discussed separately, but fish catches were rather poor, around 100 kg/hour, but higher in the north (off Mangalore) mainly of small sized uneconomic varieties. Towards the end of 1967 the surveys were extended into deep water off Cochin where good catches of deep sea prawns (*Parapandalus*, *Aristaeus*, etc.) were taken (Rao in press), but it is not known how large the fish catches were.

Catches off the east coast of India have been discussed by Rao (1969). Catch rates tended to increase from south to north, and were generally lower than on the Indian west coast. Government of India vessels from the Tuticorin base operating between Cape Cormorin and Pondicherry (12°) averaged 106 kg/hour in 1961-5, those from the Visakhapatnam base (mainly fishing between 17°N and 21°N), averaged 120 kg/hour. Rather higher rates (210 kg/hour) were achieved by Indo-Norwegian Project vessels fishing in the Gulf of Mannar and Palk Bay, but nearly all the catch (over 90%) were low valued silver bellies (Leiognathidae).

Surveys in the northern part of the Bay of Bengal have been carried out in collaboration between FAO and West Pakistan (FAO/UN 1965, internal reports of the UNDP(SF) project). The best fishing (up to 500 kg/hour) is in a band about 20 km wide between 5 and 30 fm (10-60 m), extending from off the Indian border to Coxes Basar. Catches in water deeper than 60 m were very poor.

Observations off southern Burma have been reported by Druzhinin and Hlaing (in press). Catches of F.V. LINZIN (250 tons, 500 HP) averaged around 200 kg/hour, being rather higher in the southern (around 13°N), than in the northern (ca 14°N) part of the survey area.

Finally exploratory fishing has recently been carried out by Thailand off her west coast; catches have been comparable with those in the Gulf of Thailand in the period before the development of large-scale trawling.

Most of these areas are only lightly fished for demersal species, except very close inshore. The exception is off the west coast of India and Pakistan, especially near Bombay and Karachi, where fishing is intense; despite this, catch rates in the area are good. Fishing is also heavy around Cochin, mainly for shrimps, and the catches of fish are poor. It appears, therefore, that the parts of the Indian Ocean Shelf area covered by these surveys can be roughly grouped into three classes:

Rich: Exploited - fair catch rates (over 200 kg/hour), India-Pakistan west coast, from Karachi to ca 15°N

Fair: Little exploited - fair catch rates; or exploited - poor catch rates, Indian west coast, south of 15°N; northern and eastern coasts, Bay of Bengal

Poor: Little exploited - poor catch rates (150 kg/hour, or less), Indian east coast

To convert these qualitative descriptions into quantitative estimates, the only data from the area are the estimates above - 5 kg/ha on the Wadge Bank, and 40 kg/ha off Karachi. The basic productivity off Karachi is higher than on the Wadge Bank, but the difference is not so great as the 1:8 ratio in fish potential. It may be that the lower figure does not take full account of the smaller and less valuable species not sought out by the trawlers.

Two other figures for the Indo-Pacific region have been obtained in the section on the Western Central Pacific - 25 kg/ha in the Yellow Sea, and 50 kg/ha in the northern part of the Gulf of Thailand. Putting these together suggests potential annual yields per unit area of 50 kg/ha in the rich zone, 25 kg/ha in the intermediate zone, and 10 kg/ha in the poor zone, though these figures should be considered only as rough approximations, with a range of perhaps ± 50%.

These estimates, again in default of anything better, may be extrapolated to other parts of the Indian Ocean. To the westward, it appears likely, from the oceanographical conditions, that the richness of the grounds off the northwest Indian peninsula is continued round the coast of the Arabian Sea, including the east coast of Somalia, probably as far as 5°N. The rest of the coast of east Africa south to the Zambesi appears to be unproductive; in any case, the shelf is narrow, so that the total bottom resources are small and the steepness and roughness of the bottom makes bottom fishing, at least with nets, difficult. Further south, the potential may be rather higher. In default of further evidence the density of stocks round Madagascar will be assumed to be similar to that off the African coast.

These very rough estimates for the bottom resources of the western Indian Ocean may be summarised as in Table H3.

Table H3 - Potential demersal resources of the shelf regions of the western Indian Ocean

Region	Area ('000 km^2)	Density (kg/ha/year)	Potential ('000 tons/year)
South Africa	140	25	350
Mosambique	120	25	300
Tansania-Kenya	10	10-20	10-20
Somalia (2°S-5°N)	50	10-20	50-100
Somalia (north of 5°N)	70	50	350
Arabia and Gulf of Aden	80	50	400
India-Pakistan (north of 15°N)	245	50	1,250
India (south of 15°N)	75	25	180
Red Sea	180	10	180
Persian Gulf	240	25	600
Madagascar	210	25	525
TOTAL	1,420		4,225
Oceanic Islands (larger fish only)			250
TOTAL, all bottom fish			4,475, say 4,500

A similar extrapolation can be made to the south-eastward. The area off Malaya is probably similar to that off Thailand, i.e. with a moderate production.

Little is known of conditions along the western coasts of Indonesia, but there is at least local upwelling, and productivity may be high.

Japanese trawlers have worked off northwest Australia, but not very intensely or for a long period, so that the potential is probably no more than average.

The potential of the eastern part of the Great Australian Bight was considered in the chapter on the Southwest Pacific. It appears to be a very poor area, with a potential estimated from exploratory fishing, at only 0.5-3 kg/ha. Probably the southern Australian coast, west of 130°E, has a similar potential of say 2 kg/ha.

The potential bottom fish catches for the eastern Indian Ocean can be summarised as in Table H4 - with the reservation that the estimates are in all cases very tentative.

Table H4 - Potential bottom fish resources of the shelf areas of the eastern Indian Ocean

Region	Area ('000 km^2)	Density (kg/ha/year)	Potential ('000 tons)
India-Ceylon (south of 20°N)	85	10	80
India-Pakistan (north of 20°N)	105	25	260
Burma	250	25	625
Thailand-Malaya	170	25	425
Indonesia	130	50	650
Western Australia	380	25	950
Southern Australia	260	2	50
TOTAL	1,380		3,040, say 3,000

(b) Pelagic fish

There seems little doubt that the small shoaling pelagic fish (sardine, anchovies, mackerels, etc.) form a large resource in several parts of the Indian Ocean, especially in the Arabian Sea, and one that is less than fully exploited (e.g. Panikkar and Dwivedi 1966). There is, however, very little information from which this general impression of rich resources can be expressed in a quantitative form.

The biggest present catches of pelagic fish are taken off the Indian southwest coast. The most important species is the oil sardine (Sardinella longiceps) of which the catches fluctuated widely. The worst recent year was 1956 (7,400 tons) and the best 1964 (274,000 tons) (Prabhu 1967); in the last few years catches do not seem to have fluctuated so much (Appendix Table H2). The reasons for the fluctuations are not known with complete certainty. Possible reasons are real changes in the abundance of the stocks (year-class changes), or changes in the pattern of migration (nearly all fishing is done close inshore, and if the fish remain offshore catches would be low). Bennett (1968) suggests the fluctuations are of year-class strength, correlated with the abundance of the existing stock.

There is no evidence that fishing is having any serious effect on the stock; equally, the natural fluctuations are such that fishing could be having a large effect without being detectible, especially since the same pattern of fishing - large number of small inshore vessels - has been in existence without much change. Also there are no good records of total fishing effort.

The same remarks hold good of the other major pelagic fishery round India, that for Indian mackerel (Rastrelliger kanagurta). Fishing takes place on both coasts, and recent catches have fluctuated between 25,000 (1964) and 130,000 tons (1960) (Venkatavaman 1967).

Substantial and increasing catches of mackerel (R. kanagurta and R. neglectus) are being taken by Thailand and Malaysia on the eastern side of the Bay of Bengal, and in the Strait of Malacca; it is believed (Menasveta personal communication) that the Thai and Malaysian fishermen, each taking 40-45,000 tons of fish in 1967, are harvesting the same stocks of mackerel. The Thai fishery or the

Indian Ocean coast has developed very recently, and though results of stock assessment studies are not yet available, it is likely the effects of this new fishery will soon become apparent, and enable some quantitative estimate of the resources to be made.

In the other fisheries in which substantial quantities of pelagic fish are probably caught along the coast of the Arabian peninsula, and off Indonesia, reliable information even of total catch is not available, still less any data from which assessments could be made.

Eggs and larvae

Wide-spread collection of fish eggs and larvae were made during the International Indian Ocean Expedition (IIOE), but have not yet been fully worked up and published. An analysis of the numbers of eggs and larvae, without distinction of species, has been made by Peter (1967). The maximum concentration of eggs (over 400/haul) occurred east of Socotra Island, and in the Gulf of Oman. Larvae were common in these areas, and also off the central part of the Indian west coast, and at the head of the Bay of Bengal. A preliminary examination has been made of the species composition of samples from 50 stations by Ahlstrom (1968). These were grouped into three zones - oceanic (19 stations), intermediate (27 stations) and coastal (4 stations).

The oceanic stations were dominated by larvae of deep sea fishes, two families (Myctophidae and Gonostomatidae) accounting for three-quarters of the larvae caught.

The intermediate stations also contained large numbers of these families, but in addition numbers of anchovies (12% of the total) and of several predominantly demersal families (ca 20% in all) were caught.

In the very limited number of coastal stations anchovies again accounted for about 13% of the total, and nearly all the other identifiable larvae belonged to bottom-living groups (Scorpaenidae, etc.).

A surprising feature of the collection, noted by Ahlstrom, was that only one clupeoid larvae was found, and no specimens of Rastrelliger, though a few Rastrelliger larvae had previously been identified by Peter (1967) in other IIOE material.

The data are too few to attempt quantitative assessments, but some general conclusions seem valid.

(a) As in other regions, myctophids and gonostomatids form a major resource in the oceanic areas.

(b) There is a large resource of engraulids (anchovies).

(c) The oil sardine and mackerel resources are not extremely large, and their potential may not be much above present catch levels.

(d) In the coastal zone the demersal species may form the bulk of the potential fish resource.

Another approach to the estimation of resources is from primary production.

On the basis of some measurements of primary productivity in the Arabian Sea area, Schaefer (as reported in Shomura et al. 1967) indicated that the potential yield from the Arabian Sea could be as high as 10 million metric tons. The study made by Subrahmanyan (1959) is interesting in that it represents another estimate of the potential yield from a relatively large portion of the coastal waters of the Arabian Sea. On the basis of his studies on phytoplankton, Subrahmanyan estimated the phytoplankton production along the 1,200 mi (2,224 km) coast of India and extending offshore for 50 mi (93 km) as 1.8×10^9 metric tons. Subrahmanyan indicated that the annual catch of fish from the west coast of India for the period 1950-4 was about 455,000 tons; the fish was thus computed to be 0.025% of phytoplankton relationship. He compared this ratio with that for the English Channel, an area of intensive fishing. For the English Channel, Subrahmanyan stated that the 1928 fish catch was 71,000 tons and the phytoplankton production was estimated at 15 million tons. If the assumption is made that the fish-phytoplankton relationship of 0.06% for the English Channel is a reasonable average figure, then the fish yield from the west coast of India could be increased by a factor of 2.5 to 1.119 million tons. This is approximately equal to the estimated demersal potential of the area given in Table H3.

Cushing (1969) in his review of the upwelling areas of the world estimated that the carbon fixation in the upwelling areas of the western Indian Ocean was 70×10^6 tons, with a corresponding estimate of production at the tertiary level of around 10×10^6 tons wet weight. He also gave corresponding estimates for the area of northwest Australia, and Java, of 50×10^6 tons carbon, and

7-8 x 10^6 tons wet weight of tertiary production. He believed that half to one-third of the production could be harvested by man, giving estimates of say 4 million tons in the Arabian Sea, and 3 million tons in the Java-Australian zone. Probably, in common with other upwelling areas, most of the production is of pelagic fish. This is in general agreement with the demersal estimates in Tables H3 and H4 of 0.65 and 1.6 million tons respectively; these would imply other potential resources of about 3.5 and 1.5 million tons, most of which are likely to be shoaling pelagic fish. These estimates are probably as reliable as can be obtained with present information.

Off the Indian west coast, the egg and larval data, and the close agreement between estimated demersal potential and potential estimated from primary production suggest that the pelagic potential is not very great. A guess might be a little higher than recent catches, say 500,000 tons, though this could be an under-estimate.

In the Bay of Bengal, and eastward to Malaysia, there is very little evidence concerning the pelagic potential. In the northern part, off East Pakistan, vessels of the FAO/UNDP project have noted echo traces in mid-water, which might be small fish or zooplankton; though extensive they are rather diffuse and do not suggest a very promising resource. Also the traces do not extend far offshore over the deeper water. Probably in this area the pelagic resources of shoaling fish (sardines, mackerel, etc.) are rather less than those of demersal fish, and may be of the order of 1 million tons, for the whole Bay of Bengal.

In the extreme southeast of the Indian Ocean, south of the Indonesia-northwest Australian upwelling area, there is again very little information on pelagic fish. The estimate of demersal potential, principally derived from limited exploratory fishing on the Great Australian Bight is very low - 50,000 tons. The pelagic potential may not be much higher - say of the order of 100-200,000 tons.

The western side, off the African coast south of the Somalia upwelling area, does not appear to be highly productive. The nature of the coast generally with a steep and narrow concentrated shelf suggests that the pelagic resources are likely to be rather larger than the demersal ones - estimated in Table H3 as 730,000 tons. One million tons is a round figure which might be a fairly reasonable estimate.

Mass mortalities

A feature of the northwest Indian Ocean has been the occasional occurrence of dead fish on the surface over wide areas. The most striking such mass mortality occurred in 1957 when quantities estimated as high as a million tons occurred in the central Arabian Sea between 60° and 70°E, and 10° and 20°N (Pannikar and Dwivedi 1966). The species concerned have not been definitely identified, but the occurrence confirmed the existence of large fish resources of some kind in the area.

A more local mortality has been reported by Foxton (1965), who found large numbers of small inshore species (mostly porcupine fish, *Cyclicthys echinatus*) close inshore between 9° and 12° along the Somali coast, probably killed by the upwelling of cold water. The quantity of fish observed was probably consistent with the estimates of potential noted above.

Cephalopods

There is little information about the resources of cephalopods in the area, even in comparison with the same data on fish. Almost certainly the production of larger animals in the upwelling areas will include a substantial quantity of squids, possibly at least several hundreds of thousands of tons.

6. SUMMARY AND DISCUSSIONS

The estimates in the above sections may be summarised in round figures as shown in Table H5 (including also estimates of crustacean and tuna resources taken from the relevant chapters).

These figures should be treated with a fair degree of caution; the tuna and larger crustaceans are likely to be fairly accurate, the others, with the exception of the cephalopods, are probably accurate within a factor of two, and possibly within 50% of the true value. They do show with a fair certainty that present total catches of fish from the Indian Ocean could be greatly increased, even if some individual stocks (large tuna, some shrimp, possibly some local stocks of demersal fish) are fully exploited.

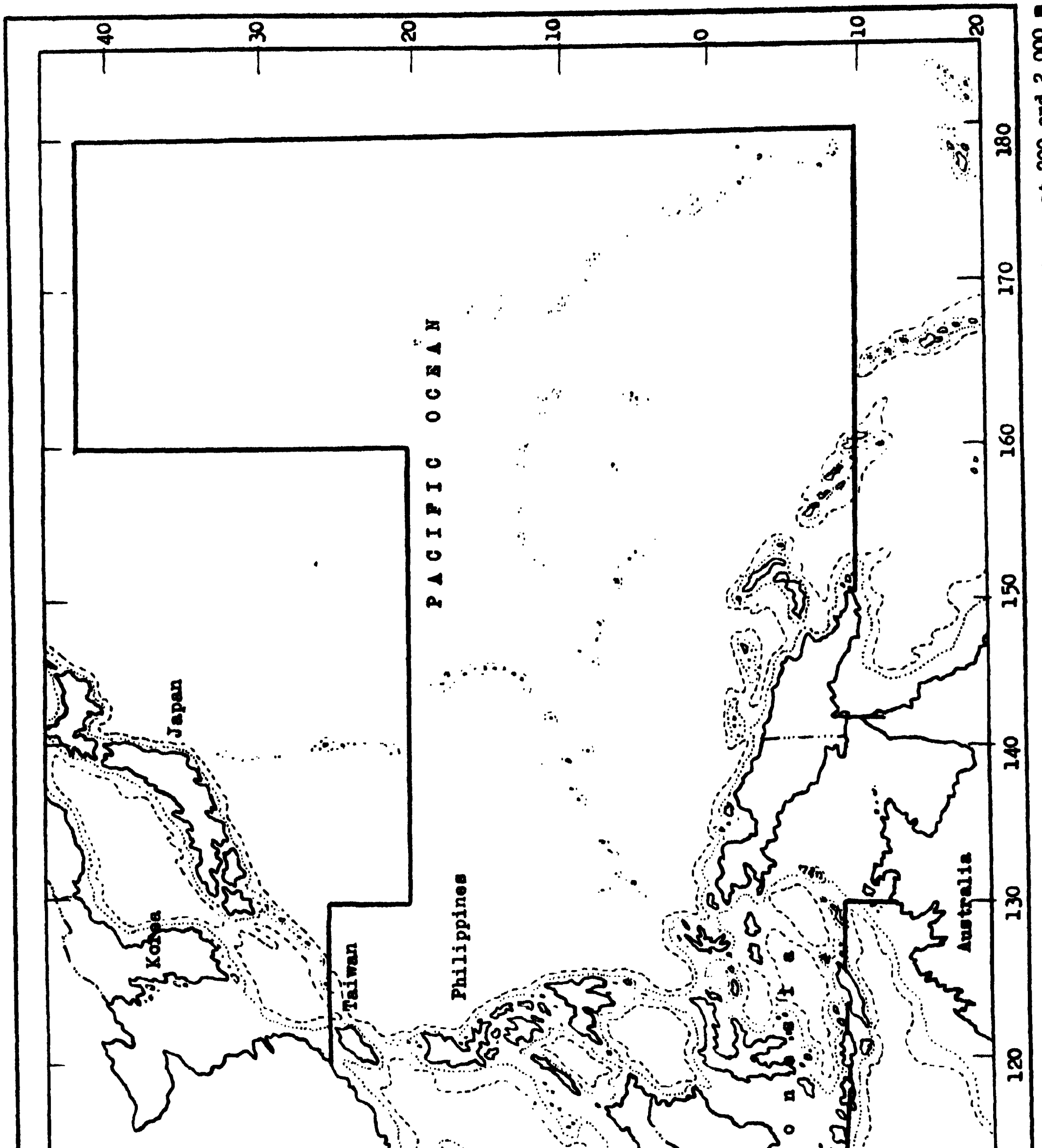
Table H5 - Estimated potential annual catches ('000 tons), from the Indian Ocean

Species	Western Indian Ocean	Eastern Indian Ocean
Demersal fish	4,500	3,000
Shoaling pelagic fish	4,000	2,000
Tunas and skipjack	- 300 -	
Crustaceans	150	100
Cephalopods	(x100)	(x100)

Much can be done to improve the estimates. Assessments of existing fisheries could be improved by better statistics of catch and fishing effort, plus related data on size and (where possible age) composition, growth, mortality rates and stock separation. While there is a large volume of biological data on fish in the Indian Ocean, little of it is directly related to the commercial fisheries.

Though most of the observations made on the IIOE are not immediately useful for estimating resources, some of the data could be so used. In particular, the examination of collections of material of eggs and larvae could be carried forward from the preliminary analysis described above to provide a much better estimate of the adult stock and spawning distribution of the major species. Such examination may show whether further egg and larvae surveys, in selected times and areas, might produce useful information at reasonable cost.

Other surveys which appear likely to yield useful results are trawl surveys in the less known areas, especially in deeper water off most coasts, and along the Indonesian coasts. For pelagic fish, echo surveys seem especially promising. Promising traces have been observed by oceanographic vessels off southern Arabia, but a systematic survey, preferably backed up with a fishing vessel with suitable equipment (purse seine, or mid-water trawl) should provide much better estimates of the magnitude of the resource, and of the practical prospects of developing a fishery. Other fruitful areas for such surveys appear to be off the Indian west coast, especially beyond the range of the existing fishery (this may well reveal whether or not most of the stocks are being exploited) and off Indonesia.



Depth contours at 200 and 2,000 m

Coastal countries:

North Vietnam Cambodia
South Vietnam Thailand
Malaysia

I - WESTERN CENTRAL PACIFIC

1. TOPOGRAPHY

As defined here the northern boundary is the 35°N parallel across the southern end of the Japan Sea, and from the Pacific coast of Japan to 145°E lat., thence north to 40°N lat., and thence eastward to 180° long. The western and southern boundaries are the mainland coast of Asia and the Malay Peninsula to 100°E long., thence south to Sumatra, and along the Sumatra-Java-Sunda island chain to 130°E long., the northern coast of Australia to the Torres Strait, the coast of New Guinea, and east to 180° long.

The region includes wide areas of continental shelf. From the north these are (with approximate areas in km², and n.mi² (in brackets) to the 200 m contour):

Table I1 - Areas of shallow water (under 200 m)

Area	n.mi²	km²
Yellow Sea and East China Sea (to the north end of Taiwan)	(275,000)	950,000
Formosa Strait and Chinese south coast	(82,000)	280,000
Gulf of Tongking (to 15°N)	(58,000)	200,000
Gulf of Thailand (from Cape Cambodia to Malaysia-Thailand border)	(89,000)	305,000
South China Sea (from 15°N to the Equator)	(280,000)	970,000
Java Sea (from the Equator south and west to Bali)	(170,000)	580,000
Gulf of Carpentaria and the eastern Arafura Sea	(280,000)	960,000
There are also narrower areas of continental shelf and shallow waters round the oceanic islands; the approximate areas are:		
Southwest coast of Japan	(16,000)	50,000
Ryukyu Islands	(3,000)	10,000
Philippines	(63,000)	215,000
Eastern New Guinea, Solomon Islands, etc. (north of 10°N)	(27,000)	90,000

Note - Those areas are only approximate, particularly for the areas surrounding islands with narrow shelves. They have been estimated from the charts in Philip's Mercantile Marine Atlas (14th edition, 1952) which gives the 100 fm contour. There does not seem to be detailed presentation of the size of the shelf in the region. Menard and Smith (1966) give the following areas within the 200 m contour:

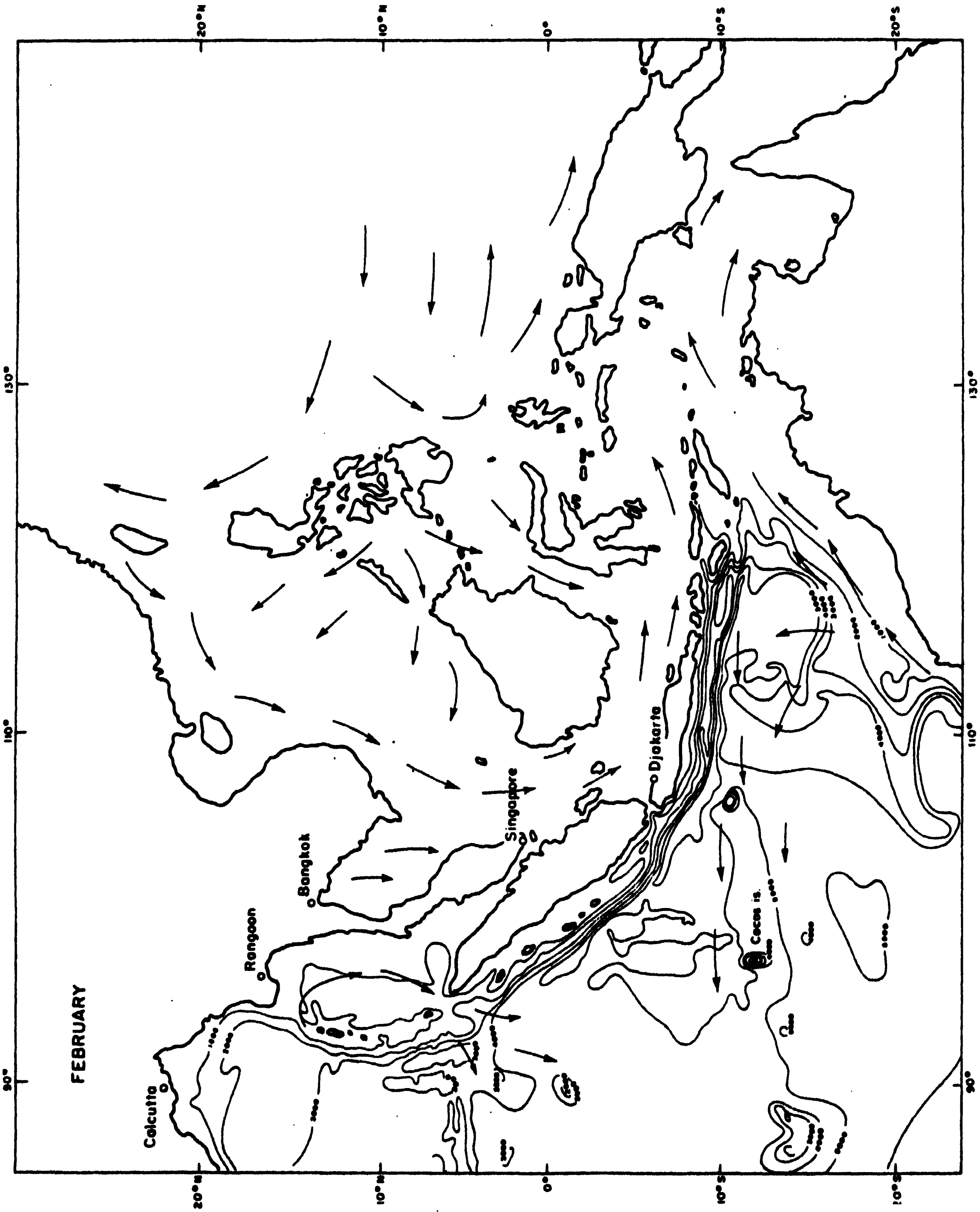
Yellow Sea and East China Sea	977,000 km²
"Asiatic Mediterranean"	4,715,000 km²

The former figure agrees well with the figure used here, but the "Asiatic Mediterranean" figure (apparently not defined precisely) is rather greater than the total of the areas above (omitting Yellow Sea and East China Sea) (= 4.17 million km²). Moiseev (1969) gives a figure of 4.5 million km² for the whole region.

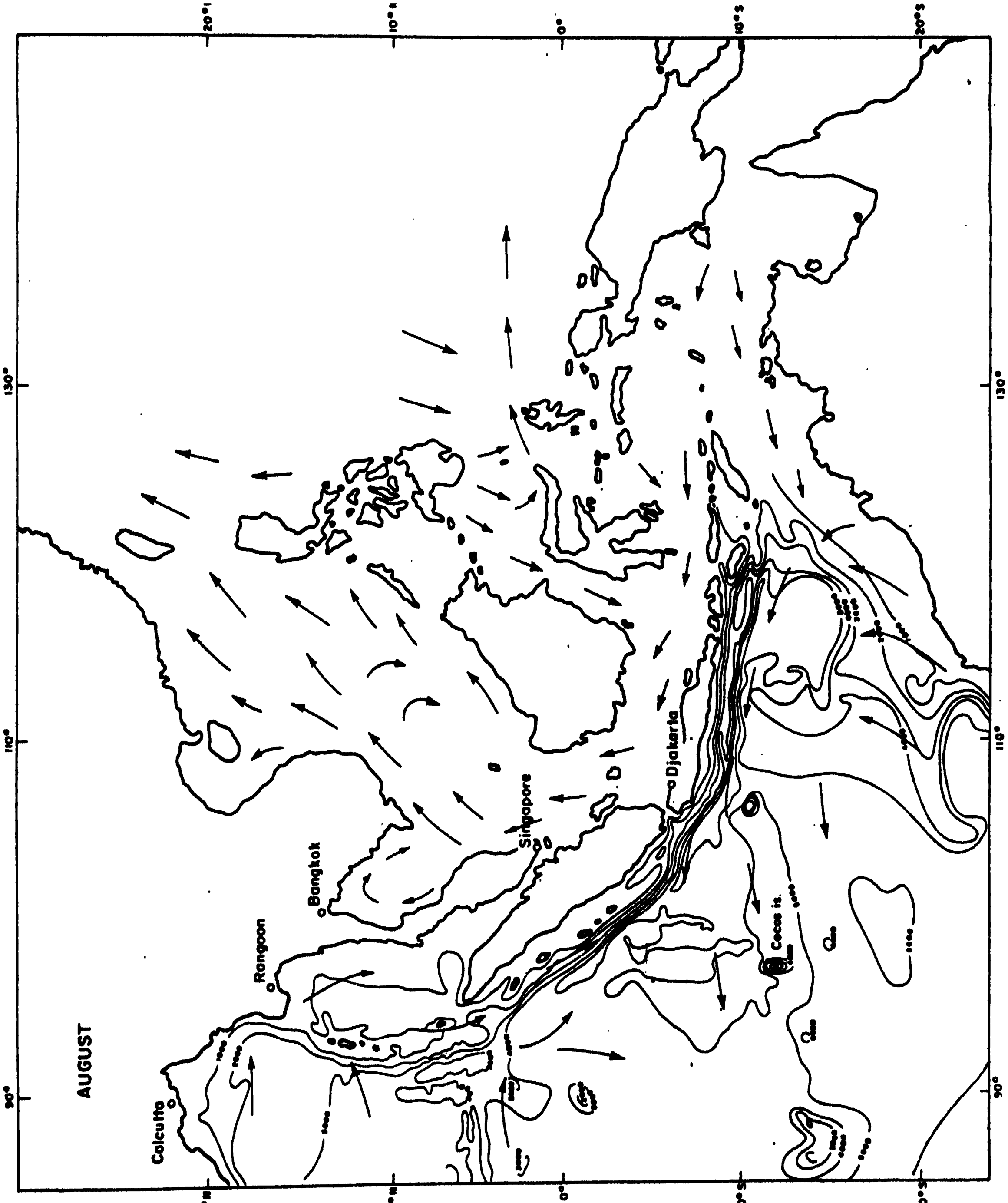
2. HYDROGRAPHY

The Western Central Pacific is dominated by the Equatorial Current system and even in southeast Asia the area is under greater influence of Pacific than Indian Ocean waters (Wyrtki 1961). A general view shows a striking difference between the northern and southern sections. In the north, the circulatory pattern is relatively constant with the strong Kuroshio Current the dominant feature; to the south the surface currents are greatly influenced by the prevailing monsoons. Many of the currents in the southern waters alternate in flow direction in response to changes in wind direction, i.e. during one part of the year the surface water flow is in one direction and during the other part of the year the flow is in the reverse direction.

The North Equatorial Current flows westward, generally north of 5°N lat., and upon approaching the Philippines separates into two branches, one directed in a general northward direction and the other in a southerly direction. The northern branch moves northward along the Philippine Islands, then along the coast of Formosa where it becomes known as the Kuroshio Current.



Surface currents in the Eastern Central Pacific in February



Surface currents in the Eastern Central Pacific in August

The southern branch, depending on the time of year, provides Pacific water into southeast Asia and also forms the basis of the Equatorial Countercurrent.

The Kuroshio moves in a northeasterly direction past the Ryukyu Islands then veers eastward, then northeastward along the coast of Japan up to approximately 35°N lat. Here the Kuroshio leaves the Japan coast and moves eastward as the Kuroshio Extension. In the Ryukyu area the Kuroshio Current sends a branch northward as the Tsushima Current. The major flow of the Tsushima Current enters the Japan Sea, while a part of the flow is deflected northwestward by the tip of Korea into central East China Sea and the Yellow Sea.

The Yellow Sea and East China Sea are characterised by pronounced seasonal changes. During the winter season, cold air moves from the Asiatic continent over these two bodies of water at an average wind speed of 2.5 m/sec. The overall cooling of surface water and the following convection allows an equalisation of the temperature of sea water from the surface to the bottom, and the strong successive blowing of cold winds by the continental high atmospheric pressure accelerates the southward advection of cooled water mass from the Yellow Sea to the East China Sea. That is to say, the enlarging of the "Yellow Sea Cold Water Mass" is recognisable. Sea surface temperatures are low, ranging from about 1°C in the north end of the Yellow Sea to 15°C at 30°N lat., 127°E long. in January. The circulation of surface water during the winter season is in a counter-clockwise direction. Water of Kuroshio origin moves northward along the eastern side of the East China Sea into the Yellow Sea. Cold surface water from the northern sector of the Yellow Sea is carried southward along the western side and leaves the East China Sea through the Formosa Strait.

During the summer season, the winds blow from the southeast at an intensity comparable to the winter period. The sea surface temperatures are relatively high, ranging from 25°C in the northern Yellow Sea to 28°C in the southern sector at about 30°N lat., 127°E long. in August. The circulatory pattern in summer is not as well defined as in the winter season. Warm water of Kuroshio origin is still deflected northward along the eastern part of the East China Sea and Yellow Sea. Along the western side, rather than a strong southerly flow as noted during the winter period, there is a general northward flow and a considerable amount of South China Sea water moves into the East China Sea.

Besides the current system just mentioned above, another important aspect of the hydrography of these seas is the remarkable tide which is particularly strong at the western coast of Korea - the range between the high and low tides is about 9 m in some places.

As indicated earlier, the circulation of surface waters in southeast Asia is complex with a complete reversal in direction of many of the currents. It is beyond the scope of this paper to describe in detail the complex nature and dynamics of this circulation. Rather it should suffice to describe the prevailing conditions during the peak of the two periods, the north monsoon in February and the south monsoon in August.

In February, the high pressure system located over the Asiatic continent is fully developed. North of the Equator the northeast monsoon prevails (Figure I1); at the Equator the winds blow from a northerly direction and from south of the Equator to 10°S lat. the winds originate from a northwest direction. The southeast trades blow south of 10°S lat. Since the axes of the bodies of water in southeast Asia generally follow the direction of the wind system, the currents tend to flow in the same direction as the prevailing winds. Figure I1 shows the general surface water circulation in February. North Equatorial water moves into southeast Asia through the south of the Philippine Islands. Along the Asiatic mainland, the currents in the South China Sea area move along the coast in a southerly direction and much of this surface water enters the Java Sea. In the Java Sea the winds are from the northwest and the currents also move in this direction with the flow moving from the Java Sea into the Flores Sea and then the Banda Sea. Part of this water enters the Indian Ocean primarily as southwesterly current in the Timor Sea just south of the Timor Islands; lesser amounts enter the Indian Ocean through the Strait of Malacca and the Sunda Strait.

In August, the South Equatorial Current is strongly developed (Figure I2) and inflow of Pacific water into southeast Asia occurs south of Mindanao in the Philippines and south of Halmahera Island. A very strong current flows in a northwest direction north of New Guinea and forms the principal water source of the Equatorial Countercurrent. The general surface circulation in the southern seas is from the Banda Sea into the Flores Sea and then into the Java Sea. The Banda Sea receives mostly Pacific water from the northeast. In the South China Sea the flow of water is northward along the continental shelf. During this period there is considerable flow of Pacific Ocean water into the Indian Ocean through the Timor Sea.

2.1 Upwelling

Undoubtedly much of the productive fisheries along the continental shelf of the Asiatic mainland result from nutrients brought up to the surface by the alternating shift in currents and localised regions of upwelling. Available oceanographic data from the western side of the South China Sea indicate localised areas of upwelling off the coast of Vietnam in June and July (Wyrtki 1961). Other areas of possible upwelling include off the coast of Macassar during the southeast monsoon and localised upwelling along the coast of China near Hong Kong during the northeast monsoon and also off the coast of Sarawak.

On the basis of upwelling, the area with the greatest potential of enrichment in southeast Asia is the Banda Sea - Arafura Sea area. Wyrtki (1961) indicated that this was an area of alternating upwelling and sinking and that during the upwelling period, which reaches a peak in July and August, the flow of upwelling water is approximately 5 million m^3/sec.

To date information on the biomass in the area is completely lacking.

3. ZOOPLANKTON

In the northern sector, the waters in and south of the Kuroshio are rather barren. The biomass (measured by the net weight of the upper 100 m) is usually less than 25 mg/m^3, with a maximum of 50 mg/m^3 in summer, and in the winter the biomass is usually 25-50 mg/m^3, with a maximum of 100 mg/m^3.

The main species south of the Kuroshio are Undinula darwini, Calanus minor and Eucalanus subtenuis; north of the Kuroshio, Calanus helgolandicus is one of the dominant species. (By Motoda and Marimo, Proceedings of Symposium on the Kuroshio 1965.)

In the southern sector, studies of zooplankton in Australian waters showed a relatively high standing crop, averaging about 100 mg/m^3, over the Australian continental shelf. In the open ocean the standing crop was considerably lower with values no greater than 50 mg/m^3, usually less than 25 mg/m^3 (Tranter 1962).

4. BENTHOS

The dominant groups in the Yellow Sea and East China Sea are as follows: Holothuridae, Macrura, Brachyura and Cephalopoda in the central part of the East China Sea, with Ophiuroidea in the northern part; Macrura, Ophiuroidea, Brachyura and Asteroidea in the southern part of the East China Sea.

Ophiuroidea are distributed in depths between 60-85 m; Asteroidea in 50-80 m and 100-150 m; Macrura in 50-110 m; Gastropoda and Cephalopoda in about 50 m. In general the peak of the distribution lies about 70 m deep.

Studies of benthos biomass in two bays in the Philippines showed considerable differences in composition and magnitude (Tiews 1959). In Manila Bay the standing crop of benthos biomass was found to be only 0.741 g/0.1 m^2 compared to the 7.957 g/0.1 m^2 for San Miguel Bay. In the Manila Bay samples the dominant groups included errantian polychaetes, macrurans and brachyurans. The major groups in San Miguel Bay were sedentarian polychaetes, errantian polychaetes and ophiuroids. The benthos standing crop of Manila Bay (area of 1,350 km^2) was estimated to be 10,000 metric tons (74.1 kg/ha) and the San Miguel Bay (area of 520 km^2) 40,000 metric tons (795.7 kg/ha).

5. FISH STOCKS AND FISHERIES

5.1 The fisheries

The region is one of the more productive areas of the world, though the large scale industrial fisheries with big ships, concentrating on a few species, characteristic of temperate waters, are absent. Instead the fisheries in the region are typically carried on by a very large number of small vessels, using a wide range of gears, and catching a great variety of species, which are usually not identified (at least down to a species level) on the fish market.

Little or no long range fishing is done in the area, except for tuna fishing in the open Pacific, but all countries in the area have a more or less vigorous local fishery supplying a strong home demand. The most striking recent development has been the growth of trawl fishery by Thai vessels, triggered off by the introduction of single-boat trawling instead of the former pair-trawling. The larger Thai trawlers are now becoming engaged in medium range fishing in the southern part of the Gulf of Thailand and beyond. Medium range vessels also operate from Japan, in the Yellow Sea and East China Sea, and from Taiwan and Hong Kong in the South China Sea.

5.2 Statistics

Recent catches by countries in the area, as available to FAO, are summarised in Appendix Table I1. Except for Japan, the statistics are of total marine fish catch, which in some cases (e.g. Thailand, Malaysia and Indonesia) include catches taken outside the present area.

(a) Japan

Statistics are generally good, and much detailed data are published in various forms. Detailed breakdown of landings is available from home landings, of which three areas - southern Pacific coast, East China Sea and Inland Sea - come within the region considered here. There is a good breakdown by species and type of gear and fair statistics of effort.

(b) South Korea

Statistics are now good (large annual Yearbook of Fishery Statistics published), with the probable exception of coastal subsistence fishing. Area breakdown is available by province of landing; those on west and south coasts come within this region. Breakdown is given by species and type of gear. Effort statistics are not very complete.

(c) North Korea

No figures are available since 1957 (then 291,000 tons). Before the war, rather more than half the total Korean catch (925,000 tons out of 1.769 million tons in 1936) came from the present North Korea. Much of this catch was sardine and this stock has very greatly declined. It is probable that the North Korean catch has increased since 1957. There are no details of species breakdown, or of area of capture (especially division between east and west coasts).

(d) Mainland China

There are no good statistics available. The most recent statistics given in FAO Yearbook are a total of 5.8 million tons in 1960, without detailed breakdown. Shindo (1964) gives a good description of Chinese fishing; of the 5.8 million tons reported, only 1.8 million tons was from normal sea fisheries; the rest being inland fisheries (2.8 million tons) and fish culture (1.2 million tons). These figures are far from being entirely reliable, but the value of marine fish catch seems reasonable in comparison with the length of coastline and the catches of adjacent countries, such as Taiwan and Korea. Shindo also gives some details of the expansion of marine fishing from 1949 to 1960, as well as the species and area breakdown in 1960. In a later study, in 1966, Shindo re-estimated the marine catch as 1.6 million tons, 1.2 million tons in the Yellow Sea and East China Sea, and 400,000 tons in the South China Sea. It is not known how the Chinese fishery has developed since 1960, but the marine catch is believed not to have increased much.

(e) Taiwan

Statistics for this region are generally good; detailed breakdown by species is available.

(f) Hong Kong

Good statistics are available for landings in Hong Kong, but much of the fleet land part of their catch (for licensing purposes) in Mainland China, and this part is not recorded. Detailed breakdown by species is given. Effort and some data are available for some of the large vessels.

(g) North Vietnam

Latest statistics in FAO are for 1962, and their reliability is unknown. The total fish catch is only broken down into marine and freshwater. Between 1955 and 1962, the reported catch increased from 94,000 to 289,000 tons.

(h) South Vietnam

Up-to-date statistics of total catch are available, broken down into freshwater fish, marine fish and crustaceans, in the FAO Yearbook of Fishery Statistics (YFS). The reported totals increase steadily from 120,000 tons in 1955 to 375,000 tons in 1965, but it is not certain to what extent this represents a real increase in catch, or merely greater completeness in the collection of statistics. Probably there are still very incomplete data as small-scale subsistence fisheries are prevalent in both fresh and coastal waters.

(i) Cambodia

Catch statistics are given in the YFS for 1961/5 with sub-totals for freshwater fish, marine fish, crustaceans, molluscs and various. The totals show a very slight increase (from 148,000 to 166,000 tons) but it is not known how reliable these figures are. There is probably a great deal of under-reporting of subsistence fishing.

(j) Thailand

Detailed statistics are available, though the YFS figures include a very large proportion of unsorted and unidentified fishes (probably mostly from the rapidly developing trawl fishery). It is known that part of the rapid increase in the total reported catch since 1961 is due to improvement in the collection of statistics. Probably the most recent figures are reasonably reliable.

(k) Malaysia and Singapore

Detailed statistics by species are given in the YFS. These are probably reasonably reliable. Some effort data are available for major fisheries.

(l) Indonesia

The reliability of the figures (1.176 million tons of marine and freshwater fish reported in 1968) is probably very low. The figures are more likely to be too low than too high because of non-reporting of subsistence fishing. Of the 1967 total (1.18 million tons) approximately 640,000 tons were believed to be marine fish. Nearly all the catch is taken by small boats in depths less than 25 m, not more than 25 mi from shore.

(m) Australia

There is very little fishing in the region. A shrimp fishery is developing in the Gulf of Carpentaria for which good statistics should be available.

(n) New Guinea, Solomon Islands, other island groups

There are very little data available, most of which are of export figures only. The latter are probably reliable, and the total catch is probably small.

(o) Philippines

The YFS gives detailed figures, broken down by species; much of these data have been derived from information which might be used for tax purposes, adjusted by a factor believed to be correct for misrepresentation. The factor used may be too large or too small. The proportions of different species may be a reasonably reliable estimate for the commercial fisheries, but these proportions may not be the same in the so-called municipal fisheries, which account for about half the total reported catch. Probably demersal fish are commoner and pelagic fish rarer in the municipal catches than the published statistics suggest.

(p) Long-range fishing

Fortunately, in view of the deficiencies in the statistics of local fishing, there is not much long-range vessel fishing in the region far from the home bases. Japanese trawlers have occasionally worked in the South China Sea and the Gulf of Tongking, and there may be developments in long distance trawling and fishing for shrimps in the South China Sea by Korea, Hong Kong, Thailand and Singapore, but this is likely to remain on a small scale. High seas fishing for tuna is considered separately in the section on oceanic resources. The main statistical problems are, therefore, confined to the countries adjacent to each area concerned.

5.3 Stock assessments for exploited stocks

(a) Yellow Sea and East China Sea

Assessments for the major stocks have been carried out by Japanese scientists. These studies have shown some degree of separation of discrete stocks within the area. However, the degree of exploitation of different stocks of the same species seems much the same. There is not much information of the degree of mixing with stocks outside the region; however, the demersal fish do not seem to migrate far. The analysis for demersal fish covers the area of the Japanese trawl fishery; this extends south to about 26°N, and therefore covers nearly the whole of the East China Sea area as used here.

The present demersal catch from the area is uncertain; from Shindo (1964) the catch of marine fish by Mainland China in 1960 was 1.8 million tons; of this, two-thirds came from the area considered, and the great majority of this total was demersal fish. Allowing for a slight increase since 1960, the 1965 catch of demersal fish may be estimated as 1.2 thousand tons. The Taiwan catch in 1965 consisted of 84,000 tons of specified demersal fish, and 61,000 tons of unspecified fish, probably nearly all demersal, i.e. a total of 145,000 tons; the proportion of this that came from the East China Sea is not known, perhaps it is as much as one-third, say 50,000 tons. The Japanese and South Korean catches are known reasonably well. It is not known what proportion of the North Korean catch is demersal fish, nor how the total is divided between the East (Japan Sea) and the West (Yellow Sea) coasts, but probably most of the catch is taken in the Japan Sea. The best estimate of the total demersal catch in the Yellow Sea and the East China Sea is as follows:

Table I2 - Demersal catches in the Yellow Sea and the East China Sea

Area	Estimated catch 1965 (in metric tons)
Mainland China	1,200,000 ?
Japan	330,000
South Korea	130,000
Ryukyu	1,000
Taiwan	50,000
North Korea	100,000 ?
TOTAL	1,810,000

A major uncertainty remains concerning the share of the total taken by Mainland China (Shindo 1964). The evidence of decline in catch per unit effort, smaller sizes of fish, and increased mortality show clearly that the demersal fisheries are approaching or beyond the level at which no further increase in average catch can be achieved. (See Anon. 1963, Mako 1961, Murakami et al. 1964 for demersal stocks generally; Misu 1965 for ribbon fish (hairtail), Trichiurus lepturus; Ikeda 1964 for yellow croaker, Pseudosciaena manchurica; Otaki 1964 for sharp toothed eel, Muraenesox cinereus; Shindo 1964 for yellow sea bream, Taius tumifrons). The trends since 1953 in catch and catch per unit effort for different species have been different; some tending to increase, e.g. ribbon fish and shrimp, at least up to 1961, while others have decreased sharply, e.g. lizard fish (Murakami et al. 1964). Most recently the catch per unit effort even of those species which have been increasing have tended to flatten out or decrease. These differences are probably due to several causes, including:

(a) changes in the balance of species in the sea, independent of fishing;

(b) relative decreases of species most vulnerable to fishing;

(c) switching of the main fishing concentration from the initially preferred species;

(d) development of new fisheries, e.g. for shrimp.

Because of these differences, it is most unlikely that the intensity of fishing is the same for all stocks, and while all the demersal stocks included in the above analysis are at least moderately heavily fished, it is likely that the yield of some could be increased by heavier fishing, while the yield of others could be increased by reduced fishing. In addition, the yield of several species might be increased by the use of larger trawl meshes. Potentially, therefore, the yield of the presently exploited demersal fish could be increased (perhaps by 10-30%), but much of this increase would require rather detailed control of fishing. It is probably unrealistic to expect much change from the present total. A potential yield of 2 to 2.4 million tons corresponds to a yield per unit area of ca 25 kg/ha.

Pelagic

Estimates of the present and potential yields of pelagic fishes from the Yellow Sea and the East China Sea are provided in the following table. The figures for Mainland China and North Korea are both very rough, assuming about one-third of the Korean catch are pelagic fish, but, following Shindo (1964), that the pelagic catch is small, say 10% of the total.

Table I3 - Pelagic catches in the Yellow Sea and the East China Sea

Area	Estimated catch 1965 (in metric tons)
Mainland China	100,000 ?
Japan 1/	350,000
South Korea	100,000
Taiwan 2/	20,000
North Korea	100,000 ?
TOTAL	600,000 ?

Notes - 1/ Jack mackerel and mackerel

2/ Assuming East China Sea catch is one-third of total

Studies have been made by Japanese scientists of the major species. The two species of mackerels (Scomber japonicus and S. tapeinocephalus) are mixed in the statistical records while catches have recently increased very greatly in other parts of Japan, the catches in the present area have not changed much. Effort and catch per unit effort data also show little change, but the effort figures do not take into account improvements in the gear efficiency. Size and age distributions show a dominance of small, young fish. It is, therefore, believed that the stock is heavily fished (Tsujita 1965), though the evidence is not as conclusive as for the demersal fish.

Catches of jack mackerel (Trachurus japonicus) increased in 1958/60 due to an expansion of Japanese fishing in the East China Sea, and probably also a greater availability of the stock. Since then, catches and catches/effort have been more stable, but efficiency of the unit of effort may have increased. Average age and size is low (Mitani and Shojima 1966) and may be decreasing. There is some indication of the existence of different stocks.

Though the situation is not as clear as for demersal fish, it is the belief of Japanese scientists that these stocks are heavily exploited and catches from them cannot be substantially increased by greater fishing. Pelagic catches in Japanese waters have fluctuated very greatly, probably largely independent of fishing.

Japanese scientists have data on larval abundance of several pelagic species. It is hoped to examine these to obtain estimates of relative (and perhaps absolute) abundance of these species.

The food items of a species forming the base of large fisheries often provide clues to potential resources of unexploited species. Stomach contents of ribbon fish (Trichiurus lepturus) contained the following relative numbers of different species of fish (in brackets catch in tons from the area by Japanese and South Korean vessels) (Misu 1964).

Engraulis japonica	118	(95,000)
Trichiurus lepturus	60	(70,000)
Pseudosciaena manchurica	50	(70,000)
Argyrosomus argentatus	11	(25,000)
Other identified fish	42	

It is interesting that anchovy is the only pelagic fish taken by ribbon fish. These studies do not suggest the existence of any substantial unexploited stocks. The potential yield is probably not much more than the present total catch, perhaps 25-50% above it, i.e. three-quarters to one million tons.

(b) Other areas on continental shelf

Very little stock assessment work has been carried out and in many areas even the basic data on catches, effort, sizes, etc. are lacking. Some data are being collected in Taiwan, Hong Kong, Thailand, Malaysia and Philippines.

Demersal

South of the East China Sea area, trawling takes place along the Asiatic continent, with increased effort noted in waters around Hong Kong, Gulf of Thailand and the Philippines. More recently trawling has increased in the Strait of Malacca by Malaysia and exploratory work is being intensified in the southern sectors of the South China Sea by various countries, e.g. Taiwan and Thailand. The present fish catch from these southern waters is given below:

Table I4 - Estimated demersal catches by areas (in 1966)

Area	Catch by countries	Total (in metric tons)
Formosa Strait and Chinese South Coast	Mainland China 550,000	
	Taiwan 100,000	
	Hong Kong 50,000	700,000
Gulf of Tongking	Mainland China 50,000 ?	
	N. Vietnam 200,000 ?	250,000
South China Sea	S. Vietnam 250,000 ?	
	(total marine fish 290,000)	
	Malaysia 75,000	
	Singapore 10,000	
	Indonesia 10,000	400,000 ?
Gulf of Thailand	Thailand 337,000	
	Cambodia 30,000	
	(total marine fish 40,000)	370,000
Java Sea	Indonesia 500,000 ?	500,000 ?
Gulf of Carpentaria and Arafura Sea	Australia negligible	
	Indonesia ?	probably very small

In the area off the south coast of China, between Taiwan and Hainan, there have not been detailed stock assessments, but experience from Hong Kong suggests that there has been an appreciable falling off in the catch rates, at least of the preferred species. This suggests that the potential yield of demersal fish in the area is being approached; i.e. that the potential is probably in the range of 800,000 to 1.5 million tons.

In the Gulf of Thailand, the recent rapid increase in trawling has been followed by a substantial fall in catch per unit effort (Isarankura and Kühlmorgen-Hille 1967, Tiews et al. 1967). Some further increase in catch may be possible. It appears that a large variety of species is caught and landed, though only half the catch is of fish used for human consumption (Tiews 1966). Probably all species easily taken by the present gear are exploited, if not to precisely the same extent.

Tiews (1966) has estimated the potential trawl catches of Southeast Asia from Taiwan to West Pakistan, from depths less than 50 m, as 7 million tons. For the area under consideration here, the potential yield is estimated to be 5.7 million tons. These estimates are based on two assumptions: (i) the present annual catch per unit area in the Gulf of Thailand is equal to the potential annual production; (ii) that the average potential production in other areas is equal to that in the Gulf of Thailand. As this estimate suggests that a very large increase in catch can be taken from the area, it is worth examining in detail.

An assessment of the demersal stock in the Gulf of Thailand has been made by Gulland (in press), using data on total catches, number of vessels and catch per unit effort of survey vessels given by Menasveta (1968). The last has decreased from just under 300 kg/hour in 1960 to 115 kg/hour in 1967. Making some allowance for the spread of fishing into more distant waters, so that only a proportion of the total catch in recent years comes from the survey areas in the northern part of the Gulf, there appears to be a clear and approximately linear relation between the survey catch per unit effort and the total effort. The corresponding relation between total catch and effort gives a maximum yield of approximately 400,000 tons per year at a level of fishing rather less than that in 1966.

This analysis did not take into account the changes in species composition that have taken place (Tiews et al. 1967). Some of these changes are the direct effect of fishing, e.g. the greater decline of the larger or more valuable species; others can be ascribed to the indirect effects, e.g. the increase in squids due to the reduction in their predators. Other changes, e.g. the increase in Lutjanus, which being a large valuable fish might have been expected to decrease greatly, are less easily explained. They may be due to complex fishery-induced causes, or may be completely independent of fishing. Any full analysis of the changes in the demersal fish community must, therefore, be a rather involved study. It may well be that short of an extremely detailed study, the simple study above, in which the total catch per unit effort of the survey vessels may be taken as a synthesis of all the direct and indirect effects of fishing, gives a rather better assessment of the state of the stocks generally, than a species-by-species analysis.

This is only the sustainable yield from the part of the survey area fished by Thai trawlers, which is smaller than the whole of the Gulf of Thailand. Tiews stated that fishing is not carried out below 50 m, and considered the catches come from an area of 24,400 n.mi^2 (=84,000 km^2). This is not much more than a quarter of the total area of the Gulf less than 200 m as estimated in the first section (=89,000 n.mi^2 = 305,000 km^2). Use of one or other of these areas gives values of yield per ha of 48 and 13 kg/ha respectively (4.8 and 1.3 tons/km^2 respectively). Though high, a figure of 48 kg/ha may be compared with annual catches of 20-25,000 tons from Manila Bay (150-180 kg/ha) (Tiews 1959). This figure includes some pelagic fish, and also includes fish caught inside the Bay which have grown up outside the Bay. It may therefore be an over-estimate of the harvested production of demersal fish per unit area, though some studies by the FAO/UNDP(SF) project suggest that the true demersal catches in Manila Bay may be as high as 30-40,000 tons, and suggest that this production can be quite high.

As an estimate of the productivity from all waters, the latter figure (13 kg/ha) will certainly tend to be an under-estimate because much of the fish in deeper waters, or in the south-eastern part of the Gulf (off Cambodia), will not move into the area fished by Thai trawlers; equally the former figure (48 kg/ha) may be an over-estimate of the productivity in waters shallower than 50 m, because the catches may include fish which have moved into the fished area, and therefore represent the production over a bigger area than considered by Tiews. There are no good data for productivity in waters deeper than 50 m. Data from several areas (Tiews 1966, Pathansali et al. 1967, etc.) show that trawl catches are much less in deeper waters, at least in some areas. Exploratory fishing data from the FAO/UNDP project in the Philippines, provided by J. Magnusson, show little difference in catch rate - ca 200 kg/hour - in 50-100 m, and in less than 50 m. However, the deeper water is at present little exploited, and the similar catch rates may reflect lower productivity, plus lower exploitation.

Therefore, it is best to follow Tiews in assessing the possible catches in waters less than 50 m deep separately; for this the higher figure above is probably closer to the value for the Gulf of Thailand. A likely range may be between 30 and 50 kg/ha (3-5 tons/km^2). If the other tropical and sub-tropical areas in the Indo-Pacific region shallower than 50 m, which according to Tiews cover 465,000 n.mi^2 (=1.6 million km^2), were as productive as the Gulf of Thailand, the total potential catch of demersal fish would be between 4.8 and 8 million tons. However, if the waters of the Gulf of Thailand shallower than 50 m are more productive than other parts of the region, this may be an over-estimate. There is evidence that this is so, e.g. Ichiye (in Fairbridge 1966) quotes figures of primary production of 6 gC/m^2/day at the head of the Gulf, 1-2 gC/m^2 in the central part, compared with 0.5 gC/m^2 in Philippine off-shore waters and the Celebes Sea. However, productivity round the Philippines appears to increase towards the shore and to be exceptionally high in Manila Bay.

The relative potential of demersal fish may also be estimated from a comparison of actual trawl catches, by commercial, exploratory, or research vessels. This has to be done with some caution, since trawl catches depend very much on the size and power of the vessel, type and rigging of the net, etc., as well as on the time of day. However, an increasing number of observations are now becoming available for the region. Besides covering an increasing proportion of the potential trawling area, there should be an increasing overlap in which more than one ship has fished in the same area at the same time of year, thus providing a proper opportunity for inter-ship calibration.

Lester (1967) and Menasveta (1968) have reviewed most of the published data in the Sunda Shelf area, the most important of which are the surveys carried out from Taiwan (Tsung 1962; Yee 1961, 1963; Tseng (1967), though other surveys have been made from Malaya (Ommanney 1961), Hong Kong and

Thailand (Tiews 1966). Four areas produced good catches; in the Taiwan surveys the highest catches were on the east side of the Gulf of Thailand, and South Vietnam (15 boxes, or ca 400 kg/haul), followed by the area off the Mekong (12 boxes, or ca 300 kg/haul), and the northern part of the Gulf of Thailand (7 boxes, or ca 200 kg/haul); other vessels also took good catches round Natuna Island, in the centre of the Sunda Shelf. These results confirm the higher potential of the inner Gulf of Thailand, especially since this area was, at the time of the surveys (1960/4), more heavily exploited than others.

However, the surveys also showed that demersal fish were present over the whole of the Sunda Shelf. Blank hauls occurred, as they do in all fishing operations, but there was no large area of consistently zero or very low catch. Excluding the richer areas noted above, the average catch per haul in the Taiwan surveys was 4 to 5 boxes (100-125 kg). This is perhaps half the value that would have been obtained in the inner Gulf before fishing started; probably the potential yield is in proportion to the standing crop. Reasonable estimates for the potential yield are, as extrapolated from experience in the Gulf of Thailand, therefore, 20-30 kg/ha in the richer parts, and 15-25/ha, elsewhere. These figures may be compared with the fairly good estimate of ca 25 kg/ha in the East China Sea, and the much rougher estimate of 800,000-1.5 million tons total, or 30-50 kg/ha for the Chinese south coast. The agreement is reasonably good, and using these figures, estimates of demersal potential may be summarised as follows:

Table 15 - Estimated demersal resources by areas

Area ('000 km^2)		Present catches ('000 tons)	Catch, kg/ha Present	Catch, kg/ha Potential	Total potential ('000 tons)
Yellow Sea - East China Sea	950	1,800	20	25	2,000-2,400
Chinese south coast	280	700	25	30-50	800-1,500
Gulf of Tongking	200	250	12	30-50(a)	600-1,000
Gulf of Thailand					
Thailand coast	84	337	40	50	400
Southeast coast	50	50?	10?	50(a)	250
Central	170	-	-	15-25(a)	250-400
TOTAL	305	400?			900-1,050
South China Sea					
Richer areas (b)	50	?	?	30-50(a)	150-250
Others	920	?	?	15-25(a)	1,400-2,300
TOTAL	970	400?	4		1,550-2,550
Java Sea	580	500?	9?	15-25(a)	900-1,500
Gulf of Carpentaria	960	-	-	15-25(a)	1,500-2,500
Philippines (c)	215	200(400?)	10	30-50(a)	600-1,000
New Guinea, etc.	90	?	?	15-25(a)	135-225

Notes - (a) Extrapolated from Gulf of Thailand

(b) Off the Mekong Delta and Natuna Island. Other areas may later be shown to be rich, so the figures for the whole South China Sea may be an under-estimate

(c) Studies by the FAO/UNDP(SF) project suggest that the true demersal catch may be as high as 400,000 tons, and the pelagic catch rather less than reported

The total demersal potential as estimated in this table is 9.1-13.3 million tons. This is about double the present catches, though the immediate prospects for expansion are not quite as good as this two-fold difference implies, since some of the areas where the unexploited potential is greatest are the open areas of the South China Sea, some distance from suitable markets, and where the catch rates are low, and consist of a large proportion of low-valued fish.

Estimates of the present yield of pelagic fish from the southern waters are provided in the following table. As indicated earlier, the lack of data from many localities in this area subjects the estimates of present catches to considerable error.

Table I6 - Estimated pelagic catches, by areas in 1966 (in tons)

Area	Catches by countries		Total
Formosa Strait and China south coast	Mainland China	100,000?	
	Taiwan	50,000	
	Hong Kong	10,000	160,000?
Gulf of Tongking	Mainland China	10,000?	
	North Vietnam	100,000?	100,000?
South China Sea	South Vietnam	70,000?	
	Malaysia Singapore	20,000(a)	
	Indonesia	10,000?	100,000?
Gulf of Thailand	Thailand	70,000	
	Cambodia	10,000	80,000
Java Sea	Indonesia	300,000?	300,000?
Gulf of Carpentaria	Australia	negligible	
	Indonesia	?	?
Philippines	Philippines(b)	300,000	300,000
TOTAL - all southern waters			ca 1,000,000

Note - (a) Most of the Malaysian pelagic catch is taken on the west coast, outside the present region
(b) True catch may be rather smaller

The best studied area is probably again the Gulf of Thailand and virtually all the Thai catch (of some 70,000 tons) came from north of 9°N (statistical areas I, II and IV), and even in these northern areas the catch per unit effort has increased between 1962 and 1965 roughly as much as the catch. Probably the catch in the northern areas could be increased. Tag returns have been up to 10% (Chomiurai et al. 1965) which, allowing for failure to return tags, mortality due to tagging, shedding of tags, etc., suggest that fishing is moderately high. Possibly, therefore, the catch cannot be very greatly increased (perhaps as much as doubled?). Allowing for additional catches from the southern part of the Gulf of Thailand, if the fish there are a separate stock, it seems that the potential catch of pelagic fish from the Gulf is probably 100,000 tons, and may well be as much as 200,000 tons and might even be greater.

The pelagic resources in the Gulf are, therefore, probably rather less than the demersal resources, but probably rather more than a quarter of the demersal fish. Lacking better data, it is reasonable to assume this is also true of other areas in waters less than 50 m, which would give a total pelagic resource in the shallow water zone of from 1 million tons, as a conservative lower limit, up to perhaps 5 million tons.

In deeper waters (between 50 and 200 m), the pelagic fish are probably relatively more abundant; the large area concerned implied that the total demersal stock may be quite large, even if too widely scattered to be at present commercially exploitable; and the pelagic resources are probably as large or larger. A total resource of 1 million tons from this zone would imply a value of only 4 kg/ha (0.4 tons/km^2), about one third of the lower estimate of the yield per unit area of demersal fish in the shallow zone. This is not unreasonable.

Island resources

One of the most notable features of the Western Central Pacific area is the presence of numerous islands of volcanic and coral origin. With the exception of relatively fair-sized commercial fishing carried out in the Ryukyu Islands and the Philippines, much of the fishing effort in the island areas is of a subsistence type and directed to fish and shellfish in the immediate coastal waters; primarily in the reef zone. The pelagic waters are presently fished for tunas and billfishes by Japanese, Chinese and other far-ranging fishing fleets. While some data are available from these open ocean fisheries data are completely lacking on the magnitude of the catch resulting from the subsistence type fishing around the islands. Although stock assessment estimates are not available for the fish species around the island waters, there are indications that much of the reef areas are presently over-fished; especially those located close to large communities.

Undoubtedly with proper management the yields of the over-fished reef areas can be increased; however, the total yield cannot be expected to be too great since the reef areas are relatively limited. In island waters, the resources which have not been explored or exploited to a great degree are the fishery resources in deeper waters beyond the reef zones. These waters contain demersal species such as snappers and groupers, and pelagic species of schooling fish such as scads and mackerel. To date these resources have not been fully harvested principally because of inadequate gear and marketing problems.

The estimate of the potential yield of the island waters (excluding the open sea fish species, e.g. tunas and billfishes) provided in the following table were obtained on a basis of comparability with a nearly fully exploited area, the Hawaiian Islands:

Table 17 - Potential yield for round oceanic islands in the Western Pacific

Area	Length of coastline (mi)	Potential yield(a) (metric tons)
Nampo Shoto group	153	612
Trust territory of the Pacific Islands	3,561	14,244
Gilbert Islands	626	2,504
Ellice Islands	135	540
Solomon Islands	2,464	9,856
Islands southeast of New Guinea	3,943	15,772
TOTAL	10,882	43,528

Note - (a) Based on yield of 4.0 metric tons per mi of coastline

The fish fauna of the Hawaiian Islands is similar to the fauna of the Western Central Pacific Islands. The Island of Oahu has a general coastline length of 112 mi and the waters of Oahu are the most intensively fished of the major islands in the Hawaiian chain. The present catch of neritic pelagial fish species around Oahu has been estimated to be 4.0 metric tons per mi of coastline per year. Applying this rate to the island waters (excluding Ryukyu Islands, Taiwan, Philippine Islands, New Guinea and islands to the west of these areas) in the Western Central Pacific provides a rough minimum potential yield of 43,500 metric tons of fish. It is very likely that the true potential yield of fish from the island waters of the Western Central Pacific is some multiple of the 43,500 tons provided here. A three- to five-fold increase is not unrealistic, especially since the fauna of the Western Central Pacific is considered richer than the Hawaiian fauna and there is some evidence that fishing in Hawaii has not reached its full potential. As indicated in the above table, the total coastline of the islands in the Western Central Pacific considered here is estimated to be about 11,000 mi.

6. SUMMARY AND DISCUSSION

6.1 Summary

The estimates of potential in the region are of around 9-13 million tons of demersal fish, and of 2-6 million tons, or quite possibly more, of pelagic fish. These figures are extremely rough, and the range of estimates, though wide, are certainly no wider than the inadequacy of the data. However, the information is good enough to show that there are ample opportunities for expanding fish catches in the region, with the exception of certain heavily fished areas (e.g. the Yellow Sea, and the northern part of the Gulf of Thailand). The estimates also suggest that, especially for demersal fish, the region is potentially one of the most productive in the world, exceeding for example the total potential of the rich areas of the Northwest Atlantic by some four-fold.

This is perhaps surprising in view of the fact that the region has not attracted the long distance fleets which exploit such areas as the Northwest Atlantic, Southwest Africa, etc., but may be explained by several factors. First, the shelf area is very large, so that the actual potential per unit area is not estimated to be very high. Secondly, the presumed faster turn-over and shorter life-span of most fishes in these warmer seas prevent the accumulation of large unexploited standing stocks and, under conditions of steady fishing, result in lower mean abundance from a given annual production. Also the wide variety of species in tropical areas is less attractive to industrial operations than the single-species fisheries of higher latitudes.

6.2 Requirements for further study

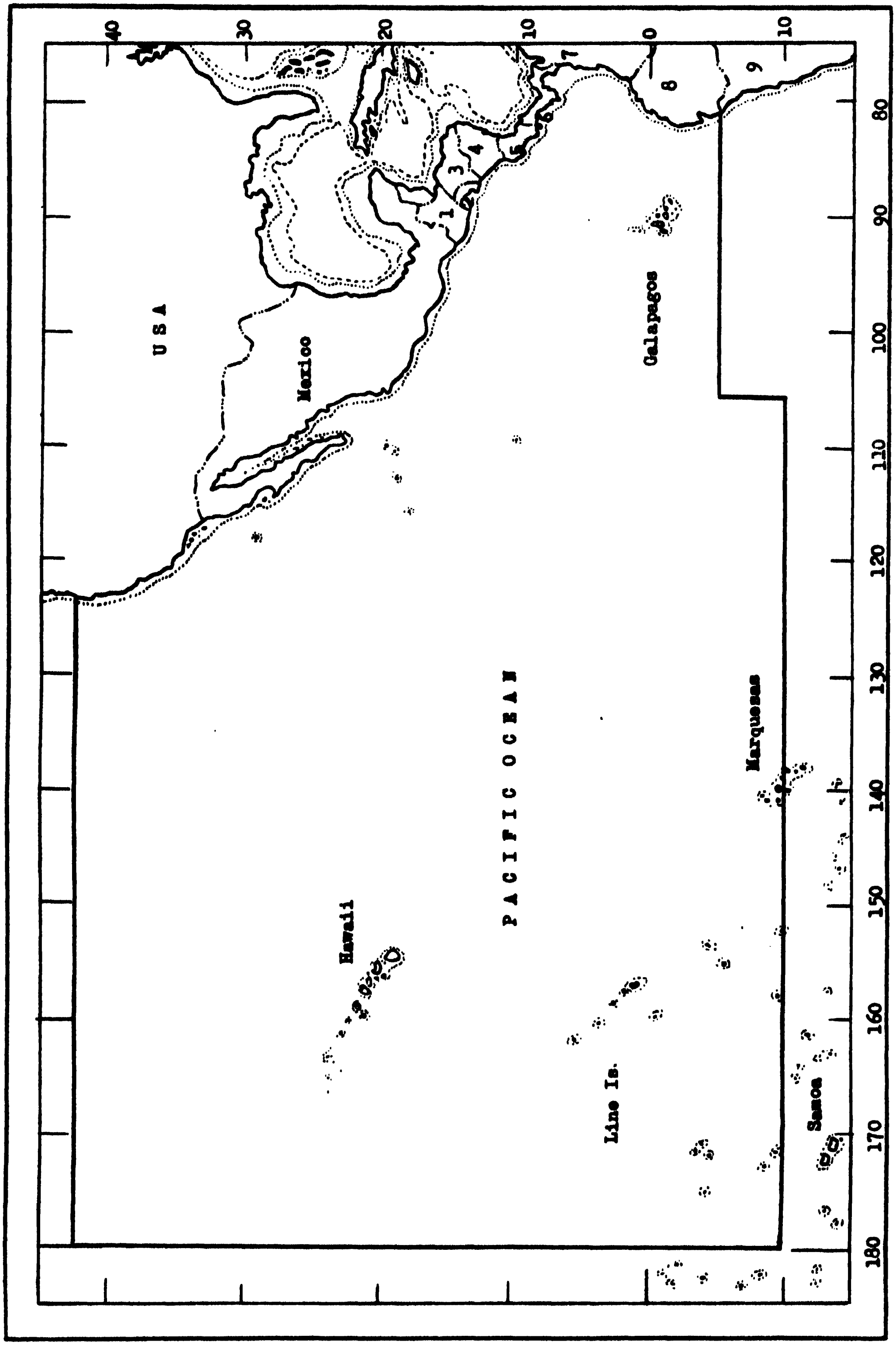
Although the available data have enabled estimates of potential to be obtained which are useful as first rough guides to the possible developments of fisheries in the area, it is obvious that much improved estimates are desirable.

The primary requirement is clearly an improvement in many of the basic statistics. It is impossible to make any useful estimate of the potential yield if the present yield is not known with any accuracy, and this accuracy is lacking in the available statistics of several countries. For nearly all fisheries there is an absence of any data of fishing effort in any form.

There are very few detailed assessments of the state of stocks and until the basic data, especially the statistics, have been improved, the number of stocks for which good assessments are available must remain small.

For most parts of the area, therefore, estimates of potential yield will have to be by comparison with other, better studied, areas. It is, therefore, important to check how valid such comparisons are. This is best done as a comparison of the stock of commercial fish, e.g. as catch per hour of a standard unit of gear, but standardisation is not too easy. Any other measure of biological productivity, from primary production onwards, would therefore be most useful, especially from the waters round Indonesia, in which data are very sparse.

Information on pelagic resources and of fish resources generally beyond 50 m depth is also sparse and urgently needs improving. Surveys with modern sonars and echo sounder gear to check on the presence or absence of shoals of pelagic fish (especially if accompanied by an efficient fishing vessel-purse seiner, or mid-water trawler) would be especially useful.



Depth contours at 200 and 2,000 m

J - EASTERN CENTRAL PACIFIC

Other coastal countries:

Guatemala
El Salvador
Honduras
Nicaragua
Costa Rica
Panama
Colombia
Ecuador
Peru

1. TOPOGRAPHY

As defined here, the coastal waters of the Eastern Central Pacific extend from northern California (42°N) to northern Peru. Conditions along most of this long length (ca 9,000 km excluding the Gulf of California) of coastlines are rather similar - a mountainous shore, with a narrow continental shelf. There are a few small islands close to the shore off southern California, and Panama. Offshore islands and banks are scarce. Isolated islands or island groups, such as Clipperton and the Galapagos, have only limited shelf areas round them, and their main importance to fisheries lies in their effect on local hydrography and on concentrating the stocks of tunas and other pelagic species.

The Californian coast is fairly straight, with no wide banks or large bays. The largest body of enclosed water is San Francisco Bay, and opposite its narrow entrance the shelf widens, though only to some 50 km. Otherwise, the shelf is on the average about 20 km. South of the Mexican border, the long peninsula of Baja California encloses the deep Gulf of California; on both sides of the peninsula and along the mainland, the shelf is narrow (from 20 up to 70 km).

Along Central America, the coastline becomes slightly more indented with a rather broader shelf, particularly in the Gulf of Panama.

The total area of the shelf, down to 200 m, at a mean width of about 40 km, and including the area within the Gulf of California, is about 450,000 km^2.

2. HYDROGRAPHY

The two major surface current systems in the region are the California Current in the north, approximately from the tip of Baja California northward and the eastward extremities of the Equatorial Current system in the south. The Peru Current and its extension as the South Equatorial Current extends into the southernmost part of the area. Also important is the Subsurface Equatorial Countercurrent.

The California Current flows southward off the American coast, and is part of the general anticyclonic gyre which dominates the North Pacific. It lies in one of the best studied areas of the ocean, especially under the CalCOFI programme (Reid, Roden and Wyllie 1958, Wooster and Reid 1963, Lynn 1967). The southward flowing current, aided by the predominantly north and northwest winds, produces strong upwelling of cool nutrient rich water along the coast, with a peak in summer (April-May off Baja California, and progressively later further north - August off Oregon). In winter, the northerly winds weaken or reverse and there is a countercurrent along part of the coast. Close inshore there is a more complex structure, with semi-permanent eddies around the channel islands of southern California, and off southern Baja California (Schwartzlose 1963).

Off Baja California the California Current swings westward and merges with the North Equatorial Current. The Equatorial Current systems of the Eastern Pacific have been summarised by Wyrtki (1966). Between the westward flowing North and South Equatorial Currents (respectively centred roughty between 10° and 20°N, and between the Equator and 10°S) there is the eastward flowing Equatorial Countercurrent. This divides on approaching the coast, the larger part swinging north along the Central American coast (the Costa Rica Current), ultimately merging with the North Equatorial Current. The cyclonic eddy thus produces results in the Costa Rica Dome (centred around 7°-9°N, 87°-90°W) (Wyrtki 1964), with considerable upwelling. Close along the coast, local topographical irregularities, and differences in wind produce a more complex system. There are some local centres of upwelling, especially in the Gulf of Panama (Schaefer *et al.* 1958). Local upwelling also occurs in the Gulf of California, depending on the wind conditions.

The distribution of high concentration of nutrients, as measured by phosphates, agrees with the upwelling areas - along the coast of California and Baja California and of Ecuador and Colombia, offshore in the Costa Rica Dome and along the equatorial upwellings, and a little along the Central American coast (Reid 1962).

3. PRIMARY PRODUCTION

The primary production in the California Current has been studied by the Scripps Institution and others, and also the more southerly area down to Peru has been sampled well in comparison with most other parts of the world. A convenient summary of primary production data for the whole Pacific has been given by Koblenz-Mishke (1967). She also derives an expression of production per unit surface from observations of production per unit volume. A summary for the eastern tropical Pacific has been given by Blackburn (1966).

Production is high in most of the coastal and offshore parts of the region, but lower in the oceanic areas well away from the coast except for a band along the Equator. Production in the upwelling areas of the California Current has been estimated as 250 mgC/m^2/day by Cushing (1969), in reviewing the production in all the upwelling areas. He estimated the total annual carbon fixation in the California Current upwelling as 30 million tons. He also estimated the fixation in the Costa Rica Dome as 15 million tons.

Production is also high in the Gulf of Panama (180 gC/m^2/year) where the phytoplankton has been studied in detail by Smayda (1966). Outside the Gulf of Panama, along the coast of Central America the production is not quite so high (15 mgC/m^3/day (Blackburn 1966) or a little over 100 gC/m^2/year).

In the Gulf of California seasonal upwelling and tidal mixing produces moderately high production, tending to increase from 0.27 gC/m^2/day in the south to 0.68 gC/m^2/day in the north (Zeitzschel 1969).

4. SECONDARY PRODUCTION: ZOOPLANKTON AND BENTHOS

Zooplankton standing crop has a similar distribution to the primary production - high along most of the coast, and along the equatorial zone. Charts of the distribution have been given, for the Pacific by Reid (1962) (in terms of parts per 10^9 by volume in the upper 150 m - approximately mg/m^3), and for the world by Bogorov *et al.* (1968) (in terms of mg/m^3 in the surface layer). Both indicate standing crops of over 100 mg/m^3 along most of the coast, with over 200 mg/m^3 in the California Current, off Central America, and off Ecuador.

The zooplankton in the California Current has been well studied, especially under the CalCOFI programme (Thrailkill 1956, 1957, 1959, 1961, 1963). The magnitude and distribution varies with the strength of the current; when it is weak, and temperatures are high, zooplankton is scarce and high densities (over 300 mg/m^3) extend no further south than San Francisco. When the current is strong, and temperatures low, zooplankton is abundant and high densities extend to central Baja California.

Further south, the zooplankton volumes in the coastal areas were estimatee by Blackburn (1966) as from 70-120 ml/1,000 m^3. Holmes *et al.* (1957) showed that the distribution is not entirely uniform, being densest off Ecuador, and lowest off Colombia, Panama and Costa Rica, though their data did not include observations actually inside the Gulf of Panama. Forsbergh (1969) found slightly higher figures and considerable seasonal variation. In the Panama Bight median standing crops varied from 100 ml/1,000 m^3 in August and November to 300 ml/1,000 m^3 in May. In the Gulf of Panama median standing crops were between 32 ml/1,000 m^3 in November and 130 ml/1,000 m^2 in June.

In common with most other areas, observations have been restricted to standing stock, with no estimates of production. Cushing (1969) estimated probable generation time of copepods from data on temperature, and hence estimated the number of generations per year, taking into account the length of the productive season. This gave 2½-3½ generations in the California upwelling areas, and nearly 10 in the Costa Rica Dome. He therefore concluded that the annual production was 2½-10 times the mean standing stock. However, the studies by Waters (1969) suggest that the production within a generation is 2½-5 times the mean standing crop; if so, the annual production of copepods might be 6-50 times the standing stock.

5. FISH AND FISHERIES

The region contains two main distinguishable faunistic areas: the tropical area, from Baja California southwards, containing a large number of species, none extremely abundant; and the temperate or sub-tropical area of the California Current, dominated by a small number of species, mainly pelagic (sardine, anchovy, mackerels and hake), the balance between which seems to fluctuate (Soutar 1967). Anchovy has replaced sardine as the dominant species since 1950. The region also includes the northern fringe of the Peru Current system, with similar fauna to that in the California Current.

5.1 The fisheries

The most favourable area for fisheries is, therefore, in the California Current, and historically the biggest fishery in the region has been, in terms of weight, that for the California sardine (*Sardinops caerulea*). Catches built up fairly steadily after 1920 to a peak of nearly 800,000 tons in 1936, and since declined, as the stock declined, to virtually zero by 1968. The reasons for the decline are not absolutely clear, and are discussed later. However, the decline in sardine was accompanied by a rise in anchovy, but for various reasons, no substantial fishery has developed on anchovy. Mackerel (Scomber japonicus) and jack mackerel (Trachurus symmetricus) are also taken in the California pelagic fisheries, but not in great quantities (mackerel peak of ca 75,000 tons in 1935, and jack mackerel peak also of ca 75,000 tons in 1952). The mackerel catches have been declining at almost as fast a rate as the sardine catch.

The other large California-based fishery is for tuna. This fishery, which is now extending into the Atlantic, as well as over most of the eastern tropical Pacific, is discussed in a separate chapter.

Also discussed separately are the shrimp fisheries, which are the major industrial-scale fisheries along the tropical coasts from Mexico to Ecuador. A small fishery in the Gulf of Panama for pelagic fish for reduction to meal and oil has very recently expanded to some 65,000 tons, roughly three-quarters anchoveta and the rest thread herrings.

Although there are no other large-scale fisheries, fisheries for both demersal and pelagic fish exist all along the coast; both for subsistence and local markets. Along the California coast, sports fishermen take substantial catches (a majority of the total catch for some species) and the interests, or presumed interests, of sports fishing have been crucial in the development of the fishery for anchovy and other species. A full description of present Central American fisheries is given by Lópes Gonzales (1967). A very recent development has been the extension of long-range trawl fishery by USSR into the northern part of the region. Sixty thousand tons, mostly hake, were taken off central California in 1967.

5.2 Statistics

Statistics of total catch are available for all countries, mostly broken down to major species. Except for tuna, little long-range fishing has been done until recently, and, therefore, place of landing provides a fair measure of place of capture. Californian vessels for pelagic and other fish fish off northern Mexico, and records are available on the general area of capture.

The main shortcomings in the statistics have been the general lack of good statistics of fishing effort, except in the few well developed fisheries (tuna, shrimp), and an absence of information on the quantities discarded by the shrimp fleet.

In most shrimp fisheries a large quantity and variety of fishes are caught. Some of the more valuable may be picked out for sale, and in some fisheries there are movements towards using the trash fish for meal production. At present, however, most of the fish are returned to the sea. Few accurate estimates of the ratio of shrimp to fish are available, but in tropical shrimp fisheries a ratio of 5 or 10 times as much fish as shrimp seems common. Studies have been made by the FAO/UNDP(SF) Central American Project which show that off Guatemala the proportion of shrimp may be even lower. Samples on board shrimp vessels in 1967 gave only 1-12% shrimp, 3-20% good quality fish, and up to 90% of the catch trash fish, suitable only for reduction to meal. Similar proportions (around 10% of the catch being shrimp) have been noted for Panama and Nicaragua (Borsbergh, 1969).

Recent statistics are summarised in the Appendix Tables. These tables include estimates of the quantities discarded by the shrimp vessels, taken as 5 or 10 times the quantity of shrimp (whole, heads on), which may be under-estimates. Off California, the catch by sports fishermen especially of bonito, rockfish and barracuda, approaches or even exceeds the commercial catch, but is excluded from most statistical data.

5.3 Stock assessment

(a) California Current

The best studied stocks in the area are the sardine and tuna. The latter are discussed in detail in another section, as are the crustaceans and molluscs.

The history of the Californian sardine fishery, and the causes of the collapse of the fishery, have been reviewed by Murphy (1966). Certain doubts about the causes of the decline are still not completely resolved. The immediate cause was a decline in the recruitment to the sardine stock; this is associated with a marked reduction in the spawning production per recruit (due to fishing) and also with a big increase in the anchovy population. Murphy obtained two separate stock-recruitment relations, for the periods 1932-48 and 1949-57 and deduced a maximum sustainable yield for the first period of 470,000 tons. Under present conditions, the yield is very small, probably negligible off California, and perhaps 30,000 tons off Mexico.

Gulland (in press) showed that the data from the two periods could be combined in a single relation between the survival of sardines from egg to recruitment, and the total spawning biomass of sardines plus anchovy, i.e. the total number of young fish competing with the individual young sardine. If this relation holds (and particularly if there is a similar relation between the survival of young anchovy and the combined biomass of anchovy plus sardine) then the potential yield of sardine (or anchovy) cannot be considered without simultaneously considering the fishing on the other species. This is the rationale of the proposed substantial increase in industrial fishing for anchovy, aimed at restoring the sardine. A dynamic relationship between sardine and anchovy is also suggested by the examination of scales in bottom deposits (Soutar 1967). This shows that the ratio of sardines to anchovies has varied greatly over a period of around 1,000 years. Since the number of scales deposited per unit biomass of fish may differ for different species (it appears that sardine scales may be under-represented in the bottom deposits), it is not however possible to use the scales to estimate the absolute value of the ratio of biomass of sardines and anchovies.

Over the period there does not appear to be any significant correlation between the number of sardine and anchovy scales in the same stratum, as might be expected if the inter-relation was a matter of simple and direct competition. This may, however, be the interaction between a negative relation (competition) and a positive one (changes in the basic productivity of the region).

Two special cases can be identified - the present situation (with virtually no sardines) and the 1930 situation (with few anchovies). If in the 1930s anchovies had been fished hard enough to maintain the balance between sardines and anchovies, the yield of anchovies would be in proportion to the standing crop, i.e. about 1/2 to 1/3 that of sardines. This gives a total of both species of 1.5 - 1.33 x 470 or 600-700,000 tons.

The possibilities of harvesting the present anchovy resource have been summarised by Messersmith *et al.* (1969). Larval surveys, based on comparison with larval sardines and the known sardine stock, give estimates of the present stock of 4-5 million tons, about half off California. Some doubt surrounds this estimate, due to uncertainties in the frequency of spawning, survival of anchovy larvae relative to sardine larvae, and escape through or in front of the nets (the smaller anchovy larvae pass through the meshes of nets designed for sardines, but may be less able to dodge the mouth of the net). An independent estimate from estimates of school size and number of schools was 1.9 million schools, each of one ton, or 1.9 million tons, off California (slightly less than the estimate from larvae).

The natural mortality of anchovy is high. The age composition given by Baxter (1967) suggest an annual survival of about 30%, i.e. if fishing is negligible, a natural mortality coefficient M = ca 1.0. Taking the present, virtually unfished, population as 4 million tons, the potential yield may be estimated, using the method in the general introduction to these studies as $4 \times 0.5 \times M = 4 \times 0.5 \times 1.0 = 2$ million tons.

This figure is considerably larger than the estimated potential yield (0.6-0.7 million) when sardine is dominant. Part may be due to the rough nature of both sets of estimates and also to some differences in the area considered - the sardine figure not including some potential from southern Baja California. However, there may well also be a real difference in productivity in the two situations due to a difference in mortality rates and turn-over rates. Thus a bigger proportion of the anchovy stock could be harvested each year.

A bigger potential yield of anchovy than of sardine would also make sense in terms of the utilization of the food resources. The growth data of Baxter (1967), for the anchovy, and of Phillips (1948), for the sardine, show that during the period of greatest abundance in the fishery (1-3 years old for anchovy, and 2-5 years old for sardine) the anchovy grows much faster than sardine (in length 10-30% for anchovy, against 2-10% for sardine; or, in terms of weight, 30-100% against 8-35%). It is, therefore, reasonable to assume that anchovy use a greater proportion of their food input for growth.

The other pelagic fish caught in the California Current are mackerel and jack mackerel. Information on mackerel has been summarised by Kramer (1969). Catches have declined with some fluctuations from a peak of 70,000 tons in 1935 to 7,000 tons in 1966 (2,000 landed in California and 5,000 in Baja California). The reasons for this decline have been discussed by Parrish and Blunt (1968). It appears that there is a sharply domed stock-recruit curve for Pacific mackerel, and recruitment is low if the stock departs far from its optimum abundance. It is believed that if fishing were adjusted to hold the population at its optimum level, sustained catches of around 40,000 tons might be possible. The present stock appears to be below this optimum level.

Information of jack mackerel has been summarized by Blunt (1969) and MacGregor (1966). As shown by egg and larval surveys, and by exploratory fishing with lights etc., jack mackerel are common and widely distributed over the area, and catches could be greatly increased over these at present. Ahlstrom (1968) estimated, from egg data, that the standing stock in the eastern North Pacific was 2.1 to 4.8 million tons - 1.4 to 2.4 million tons in the CalCOFI area. This estimate seems rather high in relation to the larval catches.

In 1955-8 jack mackerel larvae were caught in approximately the same quantities as sardine - around one-tenth the number of anchovy. As discussed below, this would suggest a biomass of only about 0.3 million tons in the CalCOFI area.

There is some suggestion that the derivation of spawning abundance from egg surveys give a high estimate. The data of Ahlstrom (originally from Ahlstrom 1959) on eggs, and of Murphy's (1966) Table 15 on biomass give the figures in Table J1.

Table J1 - Biomass of adult sardines compared with estimated egg production

Year	Biomass (Murphy) ('000 tons)	Eggs ($x10^{12}$)	Spawning biomass (males and females)('000 tons)
1951	570	610	1,694
1952	554	136	378
1953	709	436	1,211
1954	668	355	986
1955	425	163	453
1958	281	90	250
Mean	534	299	829

The spawning biomass has been estimated from Ahlstrom's (1968) relation, i.e. that 89.6×10^{12} eggs are equivalent to a spawning biomass of 125,000 tons of females, or 250,000 tons in all. Overall the agreement, taking into account the assumptions made, and the variability of much of the data, is good. The mean biomass as estimated from eggs is about 50% higher than estimated from the dynamics of the adult population. This difference is probably more than can be accounted for in variations in the latter estimate; it might for instance be accounted for by more frequent spawning by the individual female.

It is possible, therefore, that Ahlstrom's estimates for the jack mackerel may be a little high. A range for biomass of 1.5 to 4.0 million tons is, therefore, assumed here.

The natural mortality of jack mackerel is not known. MacGregor (1966) states that the commercial catches are mainly 2-4 years old (20-38 cm) suggesting a high mortality rate. However sport catches contain occasionally much older and larger fish (up to 30 years, and 75 cm), so that probably the commercial fleet only exploits a section of the stock, and that the natural mortality may be fairly low. If one fish in 100,000 survives to 30 years, the average mortality would be 0 4. A proportion of 30 year old fish much less than 1 in 100,000 would be inconsistent with their occurrence in samples, and therefore 0.4 is around the upper limit to the average annual mortality. On the other hand such old fish are not common, and a much smaller natural mortality would be surprising in comparison with that observed for other moderately small pelagic species. A range of possible values of M of 0.3 to 0.4 will therefore be used to provide rough estimates of the potential yield.

Using the methods discussed in the introduction and the above estimates of biomass and natural mortality, the range of possible values of the potential yield of jack mackerel is

$1.5 \times 0.5 \times 0.4 - 4.0 \times 0.5 \times 0.4 = 0.3 - 0.8$ million tons

or

$1.5 \times 0.5 \times 0.3 - 4.0 \times 0.5 \times 0.3 = 0.25 - 0.6$ million tons

These figures include estimates for fish spawning outside the CalCOFI area (mostly to seaward of it), which should presumably be included in the potential for the Eastern Central Pacific region. Harvesting this quantity would require an expansion of fishing beyond the range of the present fishery, probably including a change in present methods of capture and marketing.

One other epipelagic species considered by Ahlstrom (1968) is the saury (Cololabis saira). Because of the adhesive nature of its egg, egg surveys give only rough estimates of abundance - Ahlstrom gives a figure of adult stock of 225,000 tons in the CalCOFI area. Saury are attracted to light and are, therefore, conspicuous; however, larvae were scarce in Ahlstrom's survey and only 5 were taken by Berry and Perkins (1966) though the gears concerned were not suitable for either larval or adult saury. The evidence of abundance is, therefore, somewhat inconsistent. A reasonable guess at the potential yield in the present area might be 100,000 tons.

The other major species in the California Current is the Pacific hake (Merluccius productus). This is distributed from British Columbia to Baja California. Spawning is mainly in the southern part of the range, in the winter, off southern California, and there appears to be a migration north to the main summer feeding grounds off northern California, Oregon and Washington. Though related to such predominantly demersal species as the cod and haddock, the hake takes most of its food in mid-water, and also is readily fished by mid-water trawls when in large off-bottom concentrations. Due to its migrations, the resource off western North America should be considered as a whole, though occurring in two of the separate regions used in this study (this one, and the Northeast Pacific).

Ahlstrom (1968) estimated the standing crop of adults as 2-4 million tons, based on comparisons between hake and jack mackerel larval numbers. It seems equally valid to use any other species as a basis for comparison. In a later section sardine larvae have been used to estimate the adult biomass of a range of species, including hake and jack mackerel. Sardines provide the best basis for comparison, since they are the only species for which an estimate of biomass is available independent of egg and larva data, and which, fairly closely confirms the estimate based on egg counts. Using sardine larvae as a basis gives an estimate of hake biomass as 1.7 million tons. If, as Ahlstrom suggests, hake larvae are in cooler water, and developing more slowly, this might be reduced to 1.3 million tons. Scale deposition data (Soutar 1967) suggests large fluctuations over longer periods.

Estimates of hake abundance have also been made by trawl and acoustic surveys, in the northern part of its range. Alverson (1968) estimated a standing stock of 0.68 million tons north of 42°N. This figure could be consistent with any of the earlier estimates, depending on the proportion (15-55%) of the population north of 42°N. A proportion in the upper part of this range seems the more likely.

Taking a range of population sizes of 1.5-2 million tons, and a natural mortality of 0.4, gives potential yields of

$$0.5 \times 1.5 \times 0.4 - 0.5 \times 2 \times 0.4 = 0.3 - 0.4 \text{ million tons.}$$

This is very close to a Russian estimate, based on acoustic surveys, of a third of a million tons.

Of this total, about half (Alverson 1968 gives estimates of 150-270,000 tons) is available north of 42°N, and is included in the potential for the Northeast Pacific. The potential hake catches in the present area will therefore be taken as around 150-200,000 tons.

The potential for demersal fishes, other than hake, in the area is likely to be small, due to the narrowness of the continental shelf. The resources off California are discussed by Orcutt (1969). Ahlstrom (1968) reckoned that some species (e.g. California halibut) were fully utilised, and others (English and petrale soles) were approaching that level. Catches of the relatively high-valued, and shallow water demersal species (flounders, etc.) might, therefore, be increased slightly, say doubled to around 25,000 tons. The biggest potential is for rockfishes (Sebastodes spp.). Larval data suggest a moderately large standing crop - around 0.5-1 million tons. Many of the species concerned seem to be long-lived, judged by data of the same or similar species elsewhere, suggesting a low natural mortality - say 0.2-0.4. This implies a range of potential catches of

$$0.5 \times 500{,}000 \times 0.2 - 0.5 \times 1 \text{ million} \times 0.4 = 50 - 200{,}000 \text{ tons}$$

A reasonable central value might be 100,000 tons; possibly also other species would bring the total demersal potential from 42°N south to southern Baja California up to 200,000 tons.

(b) Tropical areas

Little stock assessment has been carried out in the southern part of the area (excluding the studies of tuna). Studies of the small pelagic fish used as bait in the tuna fisheries have been carried out by the Inter-American Tropical Tuna Commission (I-ATTC). The species of most importance, not only for bait, but also for reduction to fish meal and oil and for canning, are the anchoveta, *Cetengraulis mysticetus* (Howard and Landa 1958; Barrett and Howard 1961; Bayliff 1963, 1966, 1969; Forsbergh 1969), and the thread herrings, *Opisthonema libertate*, *O. bulleri* *O. medirastre*, and *O. berlangai* (Berry and Barrett 1963, Bayliff 1969). The anchoveta occurs only over mud flats, usually near the mouths of rivers. Its areas of greatest abundance are Magdalena Bay-Almejas Bay, Guaymas Bay and Ahome Point, Mexico, the Gulf of Panama, and the Gulf of Guayaquil, Ecuador. It is fished hardly at all except in Magdalena Bay-Almejas Bay, in the Gulf of Panama, and near Tumaco, Colombia. Much less is known of the distribution and fisheries of the thread herrings, but they are known to be exploited in the Gulf of Nicoya, Costa Rica, in the Gulf of Panama near Tumaco, and in the Gulf of Guayaquil.

The only attempts at stock assessment of the anchoveta appear in the above mentioned papers of Bayliff (1966 and 1969) and Forsbergh. In particular Bayliff (1966) studied the anchoveta in the Gulf of Panama, though unfortunately this study refers to a period (1960-3) when catches were much less than at present (3,400 to 8,200 tons, as compared to 53,100 tons in 1966). Within the Gulf of Panama the fish are widely distributed, but Bayliff's tagging results show that there was little interchange among the different areas of the Gulf. He estimated that, by increased fishing, the yield per recruit then taken in the main fishing area (Isla Verde) could be increased about 5 times, but he cautioned against extrapolation far beyond the range of fishing instensity at that time and also pointed out that the yield would not necessarily be proportional to the yield per recruit. He also estimated that the stock in an adjacent area (Panamá Viejo) was roughly twice as large. The total population in the Gulf of Panama during 1960 was estimated by Forsbergh (1969) as having a peak of about 170,000 tons in April. Given the high natural mortality of the anchoveta, the potential yield is probably not much less.

Little is known of the thread herrings, but they are of considerable importance because they are more suitable for canning for human consumption than is the anchoveta and because it is quite likely that the total population of these species is greater than that of the anchoveta. The latter statement is based on the fact that thread herring occur in deeper water than do anchovetas, and are not restricted to water over mud flats. Bayliff (1969) recorded a maximum catch of thread herrings in the Gulf of Panama in 1967 of 27,200 tons. FAO master fishermen have reported sighting several hundred schools of thread herring of up to 200 tons in the Gulf of Panama.

Detailed studies of the fisheries and fishery resources in part of the area are now being carried out by the UNDP/FAO Regional Fisheries Project for Central America. These should soon enable more realistic estimates of many of the resources in the area to be produced. For the present, it seems that recent catches of pelagic fish in the Gulf of Panama are towards the lower limit of the likely potential, so that further expansion in the Gulf should be possible, say to 150-250,000 tons. Though the Gulf of Panama is possibly the richest part of the southern area for shoaling pelagic fish, similar resources exist elsewhere and have been exploited for tuna bait, etc., e.g. in the Gulfs of Fonseca and Guayaquil. Taking into account the length of coastline, the total potential is likely to be in the region of 0.5-1 million tons.

Less is known about the demersal stocks. The biggest catches are taken by vessels for shrimp amd most of these are immediately discarded. Some attempts are now being made to use these unwanted fish for fish meal. The quantity caugnt is not well known, but experience in similar fisheries suggests that in addition to a quantity of high valued fish, which are kept and marketed, and therefore are recorded in the commercial statistics, the quantity of trash fish discarded may amount to some 5-10 times as great as the shrimp catches. As shown in Appendix Table J1, this implies fish catches of from 200-500,000 tons off Central America.

There are indications that in several parts of the area the shrimp are fully exploited, and that little further increases in catch can be expected. However, increased fish catches could certainly be obtained, if desired, by fishing harder in some places with gear adapted for catching fish, rather than shrimp, and possibly be measures to reduce the proportion of small individuals of the larger species presently caught in the shrimp trawls. Lacking any better estimate of potential, a figure of 1 million tons of demersal fish as the potential annual catch from the southern part of the area (Baja California to Ecuador) seems not unreasonable.

(c) Other estimates of potential

Data on eggs and larvae have been used on a species-by-species basis in the previous analysis. Two methods have been used, directly from egg counts and fecundity data, and indirectly from larvae using sardines as a basis for comparison. The use of eggs has been discussed under the jack mackerel; similar data are not available for other species.

Complete data are available of all larvae taken in the CalCOFI surveys, at least for some years. Those for 1955-8 are tabulated by Ahlstrom (1965). The relative numbers of sardine larvae, and the corresponding spawning biomass (from Murphy 1966), are given in Table J2.

Table J2 - Numbers of larvae and population biomass of sardines

Year	Larvae	Biomass ('000 tons)	Tons/Larvae
1955	14,121	425	30.1
1956	15,523	293	18.9
1957	9,833	212	21.6
1958	11,423	281	24.6
		Mean	23.8

For the four years this gives a fairly consistent ratio between the number of larvae caught and the spawning biomass, with a mean of 23.8 tons per larva. If this same ratio applied to all species, then the spawning biomass could be directly estimated from Ahlstrom's data. Clearly this is not true, due to differences in egg production per unit weight of adults per year, in survival of eggs and larvae, in ability to escape from the nets, and in growth rate, and time taken to reach a size too big to be caught in plankton nets. Some of these will work in opposite directions e.g. a greater fecundity will generally mean smaller eggs, and this, probably, a reduced initial survival of the young larvae. Probably the differences between species in the ratio of lavae : adult biomass are much less than an order of magnitude, and possibly no more than a factor of two. For species where there is no better information available, estimates within this range are helpful.

Taking a ratio of larvae : biomass of 23.8, and assumed values of natural mortality, M, as indicated, Ahlstrom's figures yield the estimates of adult biomass, and potential annual yield from the CalCOFI area, given in Table J3 (the biomass is estimated from the mean number of larvae in the 4 years).

Table J3 - Numbers of fish larvae taken in CalCOFI collections and corresponding estimates of biomass and potential

	Number of larvae ('000 tons)				Biomass	Assumed	Potential
	1955	1956	1957	1958	'000 tons	M	'000 tons
Epipelagic fish							
Anchovy	140.2	134.9	146.6	205.5	3,700		2,000(a)(b)
Sardine	14.1	15.5	9.8	11.4	300		20(a)(c)
Jack Mackerel	13.2	8.0	20.0	6.4	280		300-800(a)
Mackerel	1.9	1.5	1.9	1.3	40		40(a)
Demersal fish							
Hake	60.1	94.2	78.3	58.4	1,700		150-250(a)(d)
Rockfishes (*Sebastodes*)	29.3	29.1	36.5	23.9	710		100(a)
Sand dabs (*Citharichthys sp.*)	20.4	23.6	15.8	6.7	400	0.4	80
Myctophids							
Lampanyctus mexicanus	13.2	10.8	16.2	16.5	340	1.0	430
L. leucopsarus	7.5	15.1	16.8	11.9	300	1.0	
Diogenichthys lanternatus	4.8	3.2	11.6	7.1	160	1.0	
L. ritteri	2.0	1.9	2.8	3.1	60	1.0	
Bathylagidae							
Leuroglossus stilbius	15.1	18.6	29.5	4.9	400	1.0	255
Bathylagus wesethi	3.2	2.1	6.3	7.0	110	1.0	
Vinciguerria lucetia	12.7	9.8	55.1	55.8	790	1.0	495
Others	20.4	39.5	46.3	34.7	840	1.0	420
TOTAL	359.1	408.1	493.5	454.5	10,200		

Notes - (a) Estimate obtained from analyses in previous sections

(b) Estimate of present potential; 1955-8 lower

(c) Estimate of present potential; 1955-8 higher

(d) Potential catches south of 42°N; about half the total

One general point concerning this table, and especially the use of the same factor of 23.8 to number of larvae to biomass has been suggested to me by Dr. Paul E. Smith. He has observed differences in the shape of the length frequency distribution, and in the ratio of catches in daylight and darkness, between filiform larvae (anchovy, sardine), and fusiform larvae (hake, jack mackerel, rockfish etc.) These differences are probably due to differences in the reaction of the larvae to the nets, and in their ability to dodge out of the path. It is therefore likely that the ratio of observed numbers of larvae : adult biomass may vary systematically between two groups of larvae.

Too much consideration should therefore not be given to the actual figures in the table, but the following conclusions seem justified:

(a) there are no major resources of medium to large (over 10 cm) fish not already considered, except for a small quantity of sand dabs; (bonito are considered, with other tuna, in the chapter on oceanic resources);

(b) there is a large resource of small fish such as myctophids amounting to a potential of perhaps 1-2 million tons per year.

A similar conclusion can be reached from the data of Berry and Perkins (1966) who surveyed the area for later stages of pelagic fish, using various types of midwater trawl. The most numerous species was anchovy (34% of the total), followed by myctophids. Blackburn (1968) made similar surveys in the southern part of the area - from central Baja California to northern Chile. His data show no very obvious north to south differences, but a clear falling off in standing crop with distance offshore (20 ml per 1,000 m^3 within 300 mi, and 3 ml more than 600 mi from the coast). Myctophids were the commonest fish. A rough estimate of the standing crop of myctophids south of California can be obtained from Blackburn's data. Night hauls, to 90 m, gave an average catch of myctophids of 3.6 ml per 1,000 m^3 for the area within 300 mi of the coast. Assuming that this applies to the whole area, the tip of Baja California to Ecuador and out to 300 mi (550 km), the sampled area is:

$$550 \times 4,500 = 2.5 \times 10^6 \text{ km}^2$$

and the sampled volume

$$90 \times 2.5 \times 10^{12} = 225 \times 10^{12} \text{ m}^3$$

Hence, the volume of myctophids in the sampled region is:

$3.6 \times 225 \times 10^9$ or 800×10^6 l, say 800×10^6 kg or 0.8 million tons, close to the estimate given in TableJ3 for the abundance in the California Current. Unlike the other papers, Blackburn also considered invertebrates: of these, cephalopods were about one-fifth as abundant as fish.

As a first guess, therefore, the resources of myctophids and similar fish in the southern area - central Mexico to Ecuador - may be taken as the same as in the northern area, i.e. 1-2 million tons, and squid potential estimated as 0.2-0.4 million tons. Longhurst (1969) has briefly considered the squid potential off California, where present catches are some 8,000 tons. Greatly increased catches would certainly be possible, and the same figure as that used for the southern area 0.2-0.4 million tons appears reasonable. Longhurst also noted the large potential provided by the red crab (Pleuroncodes); this is discussed in the chapter on crustaceans.

6. SUMMARY AND DISCUSSION

The estimates of potential annual catch derived above may be summarised as follows (in '000 tons):

California Current

Pelagic		Demersal		Others	
Anchovy	2,000	Hake	150-250	Myctophids, deep sea smelts, etc.	1,500
Sardine	20	Rockfishes	50-200		
Jack Mackerel	300-800	Others	100		
Mackerel	40	TOTAL	400		
Saury	100				
Squid	300				
TOTAL	3,010				

or adding potential in the Gulf of California, in round figures, 3.5 million tons of pelagic fish and 0.5 million tons demersal

Southern (tropical area)

Pelagic		Demersal		Others	
			1,000		
Gulf of Panama:					
Anchoveta	100-500			Myctophids, etc.	1,500
Thread herring	100-150				
Elsewhere:					
Clupeoids, etc.	500-1,000				
Squid	300				
TOTAL (rounded)	1,500				

As in similar tabulations in other sections these estimates must be treated with a great degree of caution; they provide what are probably the best estimates presently available. Where only a single figure is given, this does not imply that the estimate is better than when a range is given - if anything, the reverse. A special feature of this region are the large scale fluctuations that have been observed, e.g. in pelagic fish in the California Current. Thus even if the estimates are sound for the present situation, they may be invalidated by a change in the general conditions.

With these reservations some general observations can be made. The potential of demersal fish - 1.4 million tons - is equal to an average of just over 3 tons/km^2, or 30 kg/ha. This is a somewhat intermediate value compared with other parts of the world, and agrees with the general productivity of the area - not exceptionally high, nor particularly low.

The pelagic resources cannot so easily be expressed in such comparable terms, since the boundary of the area to which they should be referred is not well defined. If the epipelagic stocks extend on an average of 200 km offshore in the California Current area, and 100 km offshore further south, then the areas concerned are about $200 \times 2,500 = 50 \times 10^3$, and $100 \times 5,000 = 50 \times 10^3\ \text{km}^2$. These would imply yields, excluding squid, of 52 and 24 kg/ha respectively, which seem not unreasonable compared with other areas.

A different comparison can be made with the studies of Cushing (1969) on upwelling areas. He estimated, from data on primary and secondary production, that the tertiary production (mainly fish feeding on zooplankton) on the California Current upwelling system to be 6-7 million tons. Much of this is based from upwelling outside the present area (north of Cape Mendoncino), but presumably a part of the phyto- and zooplankton would be carried south. Also the potential harvest by man will be only part of the production, say around half. This suggests that the figures above for the potential in the northern part of the area (4.8 million tons of all fish, including myctophids, etc.) may be rather too high.

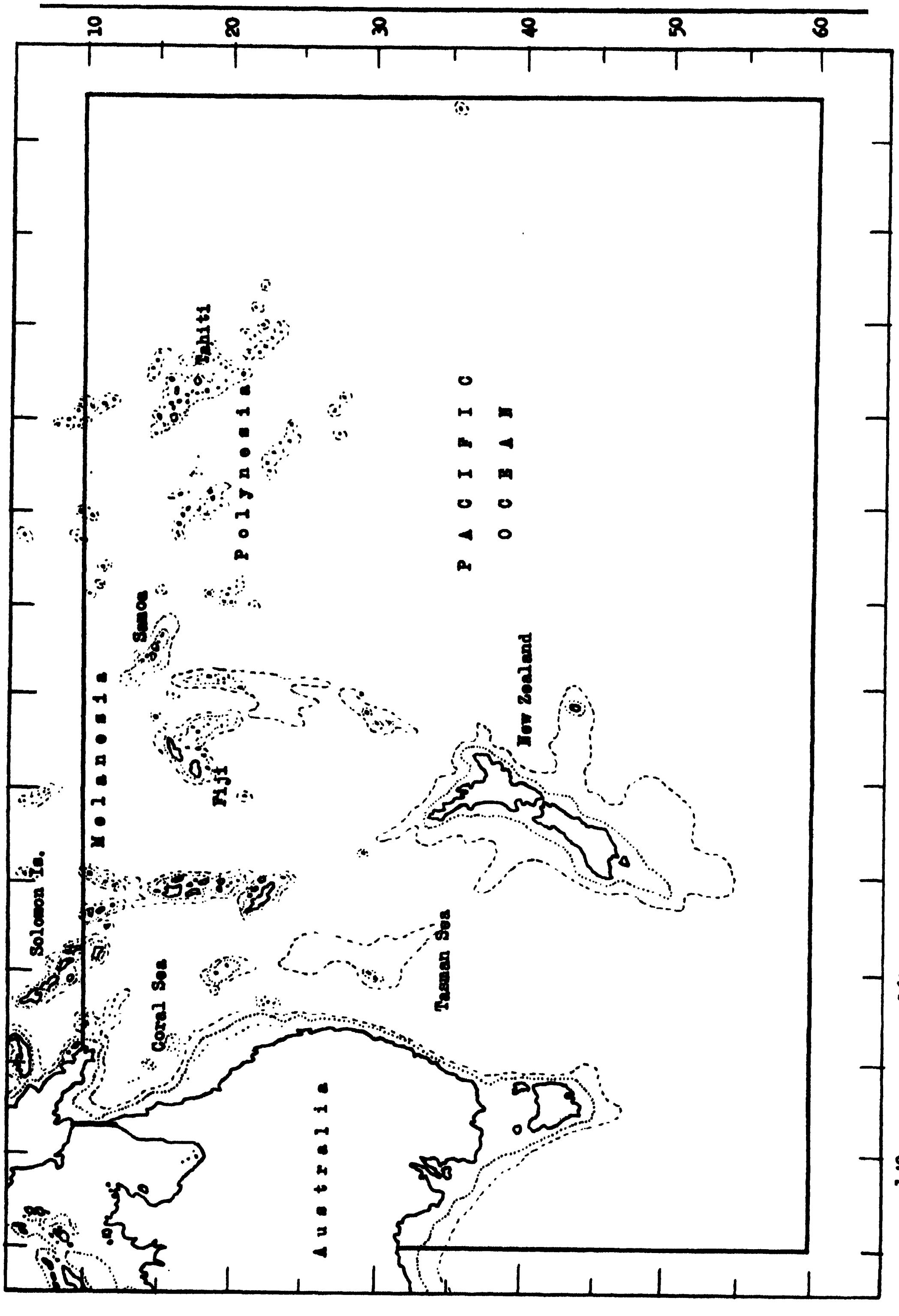
Requirements for future research

Though most of the estimates obtained here are tentative, it is not obvious, at least in the northern area, what studies could be made to produce early and substantial improvements. The California Current is possibly the most intensively studied piece of ocean in the world, and the estimates of adult standing stocks, from eggs or larvae, are probably quite reasonable, or at least about as accurate as can be obtained by such methods - though better information on the frequency of spawning would be useful. Less is known about the relation of unfished standing stock to potential annual yield. Also unknown, and possibly important, are the interactions between various stocks, e.g. between anchovy and sardine, and the degree to which it is realistic to assess the potential of each stock independently, or to consider only the total potential of epipelagic fish, without reference to species. The best way to solving most of these problems would seem to be the development of large scale fisheries on some of the presently unexploited stocks, especially anchovy.

Other relevant information would be a better knowledge of the population dynamics of the larval fish, and of the food requirements and efficiency of utilization of food by adult anchovy and sardine.

In the southern area, there are more obvious gaps in information. First the statistics should be improved, especially on the fish presently discarded by shrimp trawlers. At a minimum regular estimates are needed of the total quantity taken, with in addition as much information as possible on species composition and size composition of the major species.

Any quantitative information on the abundance of pelagic fish (with the possible exception of the Gulf of Panama) would make the estimates more realistic. This could come from direct exploratory fishing trials, acoustic surveys, or egg and larval data. Similar data, even on a comparative basis - e.g. estimates that the Gulf of Fonseca appears richer than the Gulf of Panama - would at the present stage be helpful.



Depth contours at 200 and 2,000 m

K - SOUTHWEST PACIFIC

1. TOPOGRAPHY

In total area this region is extremely large, extending, between 10° and 60°S, from Australia eastward to 115°W. Nearly all of this is deep water, and the only two major shelf areas are those round New Zealand, and off the east and south coasts of Australia (including southwest New Guinea). The western boundary has been taken as 130°E south of Australia, and as the line from Cape York to New Guinea in the north.

The shelf round New Zealand is approximately 200,000 km^2 out to about the 200 m contour. In addition to the south and east there is the large Campbell Plateau and Chatham Rise with depths of around 1,000 m, and small areas of shallower water round Chatham, Auckland and other islands. The total area of these moderately deep waters is around 300,000 km^2.

The shelf round the east and south coasts of Australia may be divided into the wide area, including the area of the Great Barrier Reef off Queensland (ca 220,000 km^2); a narrow shelf (ca 40 km wide) off the most southern part of Queensland, and off New South Wales (ca 50,000 km^2); Tasmanian waters and the Bass Strait (ca 110,000 km^2), and the Great Australian Bight, including Spencer's Gulf, and the waters off South Australia (ca 350,000 km^2 from Cape Leonwin to the Victorian boundary, of which ca 190,000 km^2 is the Great Australian Bight, as used by Kesteven and Stark 1967).

2. HYDROGRAPHY

The southern Pacific particularly away from the South American and Australian coasts is the ocean in which the hydrography is least well known. The major currents are in the north of the area (South Equatorial Current, and the Trade Wind Drift), and at the extreme south the West Wind Drift. In the Tasman Sea the well-defined East Australian Current flows south along the Australian coast, but becomes weaker and diffused south of Sydney. The current systems round New Zealand appear variable. More detailed studies of the hydrography are given, for Australian waters, in the studies of the CSIRO (Rochford 1958, Wyrtki 1960) and round New Zealand by Brodie (1960) and Garner (1969).

3. PRIMARY PRODUCTION

There has been little work over most of the region. Koblentz-Mishke (1965) has reviewed the available literature for the whole Pacific. In the northern part of the area (north of 30°S), production was low or moderate (less than 5 mg C/m^3/day at the surface, or 150 mg C/m^2/day). The waters off New Zealand and Australia south of 30°S appeared more productive, with the most productive areas (over 10 mg C/m^3, or 250 mg C/m^2) south of New Zealand and south-west of Australia. The values observed even in these areas were, however, not as high as those in other parts of the Pacific, such as parts of the coastal waters of South and Central America, British Columbia and Kamchatka. The coverage of the area is poor, and further observations are needed. A general description of phytoplankton round New Zealand is given by Cassie (1961).

4. SECONDARY PRODUCTION (ZOOPLANKTON AND BENTHOS)

No general study of the area has been made. Hela and Laevastu (1962) give a map of the world distribution of zooplankton standing crop; this suggests a moderately high value (over 200 mg/m^3) round New Zealand, and lower values (under 100 mg/m^3) off Australia, though the sources of these figures are not given. In another world-wide review Bogorov et al. (1968) give a chart which shows low to very low zooplankton standing crops (under 100 mg/m^3) throughout the entire region, except in the southern region towards the Antarctic Convergence, and along the coasts of southern Australia from the Bass Strait westwards. Better data on zooplankton are probably available for certain areas near New Zealand and Australia, but quantitative data on the benthos seem very scarce. The standing crop on the shelf off Australia, as estimated from three cruises of HMAS GASCOGNE was low - 10-20 gm/m^2 (Australia, Department of National Development 1965).

5. FISH

5.1 The fisheries

The fisheries of the area have been generally on a small scale, carried out by small vessels with a variety of gears. Round the Pacific islands fishing is mainly for subsistence. Fishing for bottom fish with trawlers, long-lines and Danish seines off Australia and New Zealand has been carried on for a long time. An Australian venture in the early 1960s with an English type of distant water trawler in both Australian and New Zealand waters was not very successful, but more recently large freezer-trawlers from Japan and Rumania have operated off New Zealand. Japanese trawl and long-line catches of demersal fish have increased slowly from 2,200 tons in 1961 to some 10,000 tons in 1965, but as the statistics show, local fisheries with small vessels still account for by far the greatest proportion of the total catch.

The most important single-species fisheries are those for crustaceans (rock lobsters, off New Zealand and Australia, and prawns off Australia). These resources and those of the open ocean, including the tunas, are discussed in more detail in separate sections.

5.2 Statistics

Good catch statistics are available for New Zealand and Australia. Effort statistics have been lacking but are now being collected in the major fisheries. Since the vessels concerned do not travel far the area details, which are generally of place of landing, correspond reasonably well to the place of capture. The statistics of the subsistence fisheries are probably not so reliable, but the absolute error is probably not large. Recent statistics are tabulated in Appendix Tables K1 and K2.

5.3 Stock assessments

(a) Demersal

Australia

ments have been made of some Australian stocks. The trawl stocks off the New South Wales coast, particularly of tiger flathead (*Neoplatycephalus macrodon*) are heavily fished (Fairbridge 1948, 1952, Houston 1955). The more recent history of this fishery confirms their analysis, and suggests that at best only small increase in catch of at least the favoured species of demersal fish in this area could be achieved, and this would require better management, particularly a larger mesh size, rather than any further increase in effort. Present catches are about 9,000 tons, including 3,000 tons of flathead.

Tagging and other research on school shark give estimates of annual fishing and natural mortality of 5% and 27% respectively (Kesteven 1966). This suggests that exploitation could be increased, to give perhaps two to three times the present catch (ca 5,000 tons), though the natural mortality may have been over-estimated. In this event the possible increase in catch may not be large.

New Zealand

No detailed assessments appear to have been made. Longhurst (1958) reviewed information on the most important species (snapper, *Chrysophrys auratus*) and concluded that the occurrence of smaller fish on the more heavily fished grounds was due to a slower absolute growth rate in those areas rather than due entirely to the effect of fishing. There was, however, also a suggestion in the length data presented that, for these areas where there was a clearly bi-modal distribution, the proportion of fish in the larger size group was less in the heavily fished areas, which is an indication of higher total mortality, due possibly to fishing. The stocks may be fully exploited in some areas, but in New Zealand waters as a whole some expansion beyond the present 8,000 tons should be possible.

(b) Pelagic

Australia

Thomson (1963) has reviewed the information on the Australian mullet, which appears to be fully exploited. The stocks of the Australian salmon, *Arripis trutta*, have been studied by Malcolm (1960), and these also appear to be approximately fully exploited (present catches ca 4,000 tons). Present catches of snoek or barracouta (*Leionura atun*) are small, and catches could, it has been estimated, be increased at least six times (Australia, Department of National Development 1965), i.e. to ca 15,000 tons. The other pelagic stock which has been studied in any detail is the southern bluefin tuna; this is discussed, with the other resources of the world, in a separate section of this report.

5.4 Other estimates of resources

Trawl surveys of some of the waters round Australia have been carried out at intervals over the past 60 years, especially in the Great Australian Bight (Houston 1954, Kesteven and Stark 1967). The most recent survey was carried out by M.T. SOUTHERN ENDEAVOUR, and the results have been fully analysed by Kesteven and Stark. The average catch rate was 0.036 tons per 100 trawler ton-hour, which is considerably lower than the rates in the Northeast Atlantic (ICES 1967 table 6) which are mostly in the range 0.09-0.18. (The figures quoted by Kesteven and Stark were of catches of individual species, which are lower than the total catch of all species.) Precise comparison is difficult because the northern stocks are all heavily fished, so the density is much less than the original unfished density, perhaps as little as one-tenth, but more probably around one-quarter; against this experienced commercial operations will, in a given area, obtain a considerably higher catch than exploratory operations - experience off the US west coast suggests a factor of up to two. This suggests that the Bight has an unfished standing crop between one-tenth and one-quarter of some north Atlantic waters. Omitting Iceland and Faroes, where it was believed much of the catches of fish were ultimately from primary and secondary production occurring off the shelf, the average potential demersal catches in the Northeast Atlantic, as estimated in another section of this report, were between 0.7 and 1.8 tons/km^2. A tenth to a quarter of these figures would suggest potential yields of 0.1 to 0.4 tons/km^2.

Kesteven and Stark calculated a mean standing crop of 3,934 lb/mi^2 (about 0.52 tons/km^2), assuming the trawl caught everything in its path. This assumption cannot be entirely valid, and the authors suggested that the figures should be doubled to give a more realistic estimate.

The potential catch, from the methods developed in the introduction to this report, may be estimated as 0.5 x M x standing crop, where M is the natural mortality coefficient. This is not known, but preliminary analysis of data for the tiger flathead off New South Wales suggested a value for this stock of 0.2 - 0.4. Using M = 0.3 as a possible mean value for all stocks gives a potential catch of $0.5 \times 0.3 \times 0.52 \times 2 = 0.15$ tons/km^2.

These figures of catch per unit area can be expressed as potential catch by multiplying by the total area concerned. The survey only covered about 15,000 n.mi^2 compared with the total area of the Great Australian Bight of 54,000 n.mi^2. Probably the density in the unexplored areas is rather less than in the areas surveyed - the unexplored areas were largely inshore of the survey area, and catch rates in the survey area were lower in the shallow water. Therefore the estimates of potential catch obtained by multiplying the above figures by the total area of the Bight (190,000 km^2) - 19,000-76,000 tons or 24,000 tons - may tend to be over-estimates.

In New Zealand waters no survey has been made. The fact that the Japanese demersal fishery off the east coast of the North Island has not developed to any great extent, suggests that the potential is not very large. This is supported by the report that the average size of fish caught by Japanese vessels has decreased during the period of this rather localised fishery. Detailed statistical data of New Zealand catches show that the catches per unit area of all species of bony fish vary from over 2 to less than 0.1 tons/mi^2 of shelf (to 100 fm - ca 200 m), and suggest that the main cause of the difference is closeness to markets and the degree of shelter. Even if the heavily fished grounds are fully exploited, the higher catch rates, if applied uniformly to all areas, would imply a doubling of total catch.

Surveys of pelagic resources round Australia have been primarily concerned with tuna (especially bluefin), which are considered separately. Bluefin tuna are moderately heavily fished (annual catches ca 8,000 tons), but appear in the southern waters; skipjack are more abundant than bluefin, and jack mackerel considerably more abundant than skipjack. Off Tasmania aircraft sightings of schools of mackerel reached a maximum of 2,000 schools, estimated at 3-50 tons per school, on one day (Hynd and Robins 1967). Since this only includes those fish which were in the survey area, and which were shoaling near the surface, the figures of 6-100,000 tons for the standing crop may be very much under-estimates.

Some survey data for sardine (*Sardinops neopilchardus*) by aircraft, and research vessel including echo sounder records, are also available (Blackburn 1960, Blackburn and Downie 1955). Off Western Australia, Rapson (1953) estimated an observed stock along 100 mi of coast as 20,000 tons. Off New South Wales, Blackburn and Downie found rather larger and more frequent traces. The area concerned is not known precisely, though the length of New South Wales coast from Port Jackson south is some 250 mi, suggesting, in comparison with Rapson's figures, a standing crop of more than 50,000 tons. Estimates of the potential yield made by CSIRO in their general survey of Australian fisheries potential (CSIRO 1966) was of over 100,000 tons of pilchard and anchovy, and 100,000 tons of jack mackerel.

Off New Zealand there are little data on pelagic stocks. Recent accounts in the popular fishery press refer to resources of a million tons, but the factual basis for this figure is not known. Commercial fishing on any scale has been restricted to a short-lived fishery for sardines for canning, mainly between 1941 and 1946, with peak catches of 300 tons (Humphrey 1960). Species which are likely to be important include the kawhai (Australian salmon, *Arripis trutta*), which is known to be common, but is not exploited in New Zealand, trevally (*Caranx lutescens*), which occurs incidentally in bottom trawl catches, sardine and anchovy.

6. DISCUSSION

6.1 Summary of estimates of potential

In Table K1 an attempt has been made to summarise the estimates of potential catches, excluding molluscs, expressed both as absolute quantity, and as yield per unit area. This table is very incomplete, though some general statements can be made. First, the proportion of crustaceans among the known resources is very high; this would seem to be due to the high economic value of crustaceans (rock lobsters and prawns) rather than real preponderance of crustaceans in the sea. In comparison with other areas, the yield per unit area of crustaceans is quite high, but of other fish very low. Thus the estimated potential in the Northeast Atlantic range, for pelagic fish, from 8 kg/ha, in the Baltic to 106 kg/ha in the Bay of Biscay, and for demersal fish from 6 kg/ha in the Baltic to 80 kg/ha off Iceland.

of this difference is undoubtedly due to real differences in productivity, for instance the ratio of the potential yields of demersal fish in the North Sea and the Great Australian Bight, is about the same as the rates of standing crop of benthos. Much though may also be due to the omission, or under-estimation of the resources in the Southwest Pacific. For example, the heavily fished grounds for demersal fish (flathead, etc.) off Southeast Australia only cover part of the total shelf - the shallower water, and especially the part south of Sydney. Other parts may not at present be able to support an economically viable fishery, but with better techniques or better prices could provide an appreciable contribution to the total catch. The estimates of pelagic resources alco appear almost certainly to be conservative estimates.

If it is assumed that, omitting the oceanic islands, and the Campbell Plateau, figures for potential yields of 10 kg of pelagic fish, and 5 kg of demersal fish can be used for purposes of illustration, then the total potentials of these areas are 500,000 tons of demersal fish, and 1 million tons of pelagic fish. To this may be added the potential round the oceanic islands, say of the order of 10-100,000 tons, plus the Campbell Plateau. This is an area where potential may be high; the productivity is moderately high, and though the water is deep it is not too deep for modern techniques. A potential of only 10 kg/ha would give a total of 300,000 tons. Clearly further study of this area would be very worthwhile.

6.2 Further studies

The previous sections have shown that for many of the resources in the area there is very little information on which to base meaningful estimates of potential. There is therefore a great need to gather further information over a very wide range, from basic productivity studies (are some of the waters in the area really as barren as the low catches suggest?) to exploratory fishing.

Direct surveying work seems particularly desirable for the demersal resources in the deeper parts of the shelf round New Zealand, including the Campbell Plateau (e.g. by a grid of trawl hauls), and for the pelagic resources generally - particularly using the modern advanced acoustic methods.

Table K1 - Estimated potential of the Southwest Pacific

	New Zealand	Campbell Plateau	Queensland	Southeast Australia	Tasmania (a)	Southern Australia	Pacific Island
Area ('000 km^2)	250	300	220	50	170	350	?
Present catches ('000 tons)							
Pelagic	3.4	-	2.7	7.0	4.6	5.5	?
Demersal	31.6	-	1.3	9.7	5.0	3.3	?
Crustacean	5.0	-	2.9	2.3	2.1	2.2	?
TOTAL	40.0	-	6.9	19.0	11.7	11.0	?
Estimated resources							
Pelagic	(75)(f)	?	?	100(e)	100(e)	50(e)	?
Demersal	(75)(b)	?	?	10	(5)	10-75(d)	?
Crustacean(c)	5	?	3	2.5	3	3	?
TOTAL	155	?	3+	112	110	(100)	?
Potential, kg/ha							
Pelagic	2	?	?	20	5.9	1.4	?
Demersal	2	?	?	2	0.3	0.5-3(d)	?
Crustacean	0.2	?	0.14	0.5	0.2	0.09	?
TOTAL	?	?	?	22.5	6.5	2-5	?

Notes - Includes Bass Strait

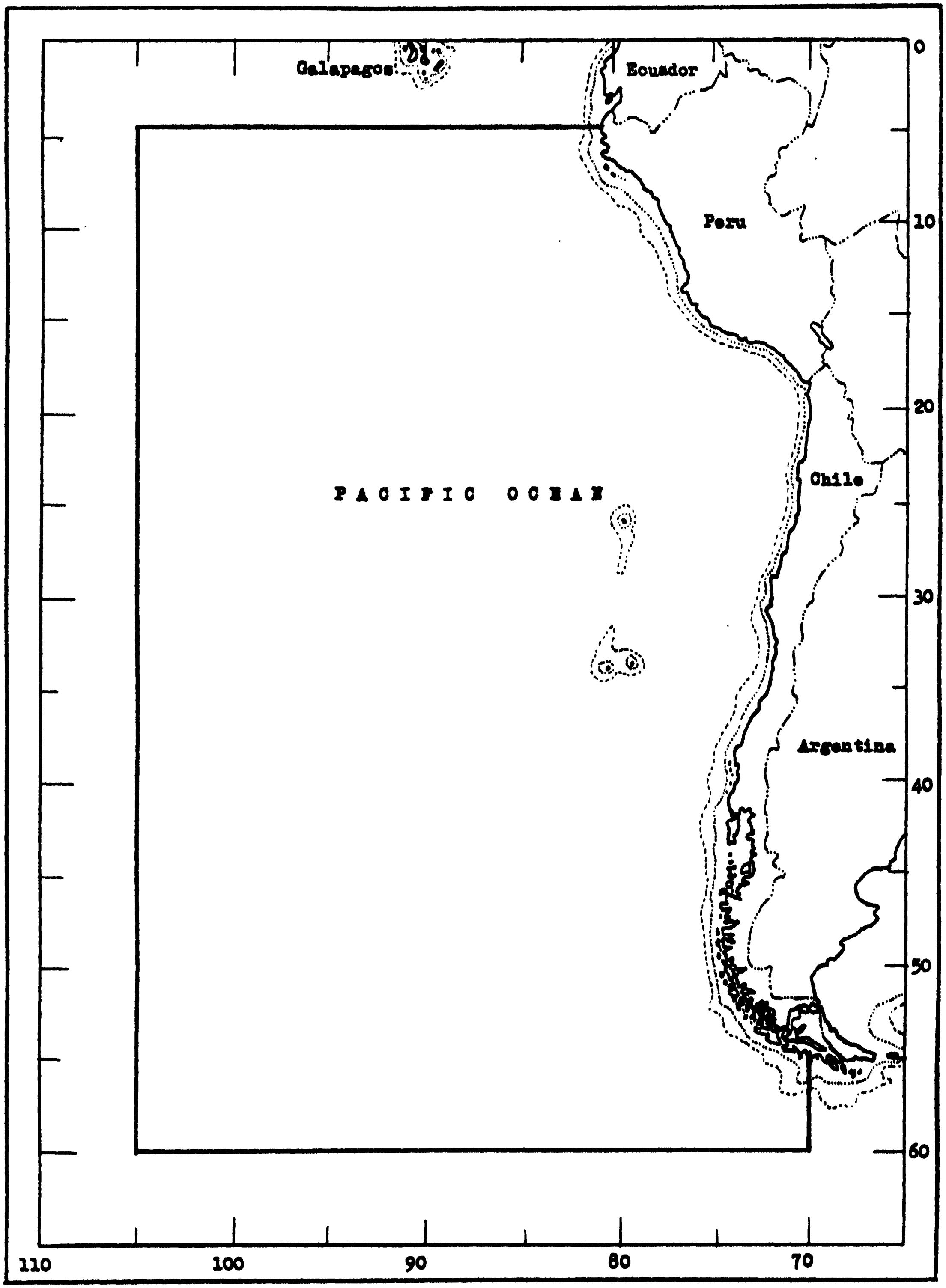
Assuming that present catches could be a little better than doubled

Assuming a moderate increase in present catches possible. For more details see separate section of world crustacean resources

(d) Great Australian Bight only

(e) Pelagic resources of tuna, barracouta (snoek) (30,000 tons), pilchard (100,000 tons) and jack mackerel (100,000 tons) have been distributed somewhat arbitrarily to the sea areas around south and east Australia

(f) Assumed equal to demersal resource



L - SOUTHEAST PACIFIC

Depth contours at 200 and 2,000 m

1. TOPOGRAPHY

This section covers the area along the coasts of Peru and Chile, south of 5°S, and is the area of the Peru Current and the important upwellings related with this current.

The shelf is very narrow in the central part of this area, from about Ilo in Peru until south of Valparaiso, in which area depths of over 1,000 m can be found within 30 km from the coast and the width of the shelf varies from a few miles to about 20 km. To the north along the Peruvian coast, the shelf gets gradually wider, until a maximum of about 130 km in the region of Chimbote, whereafter it narrows again. South of Valparaiso the shelf also widens to a maximum of about 90 km along the coast of the most southern part of Chile. This southern part, covering about one third of the Chilean coast and running from about the Golfo de Ancud to Cape Horn, has numerous islands with large fjords and wide coastal passages. The total shelf area is estimated at roughly 87,000 km^2 for Peru (within 200 m depth line) and 300,000 km^2 along the Chilean coast (total shelf area), of which the latter is estimated to contain an area of about 90,000 km^2 of trawlable ground of less than 200 m deep (Laevastu 1958, Fiedler 1952, Lengerich 1957).

The weather north of 35°S is in general favourable to fisheries, but from here towards the south the wind becomes increasingly difficult. Between 40° and 47°S, fishing can be carried out with medium to large sized boats during the summer and with difficulty during the winter, whereas further south the relative gale frequency increases further and makes fishing nearly impossible, except for very large boats or in the sheltered fjords (Laevastu 1958, Brandhorst 1965). Little information has been published on the fishable grounds in the area. The Fisheries Development Institute in Santiago has done exploratory fishing in some parts of the area.

The Peru-Chile Trench, which lies a short distance off the coast of Peru and northern Chile till about Valparaiso, reaches a depth of over 3,000 fm and at some places over 4,000 fm. Further offshore, the sea basin has for the greater part a depth of over 2,000 fm, with some shallow areas around the Juan Fernandez Islands, extending northwards as a ridge of less than 1,000 fm deep and with a minimum depth of 300 fm.

2. HYDROGRAPHY

2.1 The current systems

Sub-Antarctic water which flows east across the Pacific Ocean reaches the Chilean coast between 44° and 48°S, in summer somewhat more southerly. From here, the Cape Horn Current flows along the coast to the south and the Peru Current or Humboldt Current follows the coast northward until about the northern boundary of the area. This current system extends to several hundreds of miles offshore. Two branches can be distinguished, the offshore Peru Oceanic Current, which reaches to about 700 m depth, and the inshore branch, the Peru Coastal Current, down to about 200 m depth. The inshore branch loses strength when proceeding to the north, and reaches to north of Callao.

The Peru Current carries cool, nutrient rich water to the north and moves slowly with a speed of about 0.2-0.3 knots in the coastal area.

The surface temperature at the beginning of the Peru Current is 10°-15°C. While the current moves north, the temperature slowly increases until it reaches 18°C in the southern winter and up to 22°C in the summer in the coastal area off the north of Peru, with somewhat higher temperatures further offshore. The salinity is about 34.0 in the south and increases by evaporation up to 35.0 in the northern part of the area. (In the coastal area of the Cape Horn Current, the salinity goes down to 33.0).

In sub-surface layers an under-current flows south close to the coasts of Peru and Chile. It contains equatorial sub-surface water and appears to originate near the Equator where it is present at a depth of less than 100 m and reaches down to a depth of several hundreds of metres. It extends south to about 40°S where it ranges from a depth of 100-200 m to about 200-300 m. On the shelf, the current comes closer to the surface. The water has a salinity of 35-34.5°/oo. The entire water mass at these depths is of very low oxygen content, and high in nutrients.

Wyrtki (1963) stresses that the Undercurrent should be well distinguished from the Countercurrent, which separates from the Undercurrent in the north and flows south between the Peru Oceanic Current and the Peru Coastal Current as a weak and irregular flow. This current reaches a few hundred metres depth and only occasionally reaches the surface (between November and March). From April to June this southward flow is only occasionally observed and its location is more variable.

Along the coast there are several centres of upwelling, caused by the southerly and south-southeast winds prevailing in the area, which carry surface water away from the coast. This results in water being drawn to the surface from depths of generally less than 100 m. The coastal upwelling, therefore, represents only an overturning of the upper layers. From the upwelling centres, tongues of relatively cool water leave the coast and it seems that eddies are formed, the one branch formed by these tongues and the other branch moving inward carrying oceanic water towards the coast (see Sverdrup et al. 1946).

From December to February warm tropical water shifts southward along the coast of Ecuador, and extends in a small strip along the coast of Peru south of 5°S. In some abnormal years the water reaches much farther south, resulting in the sea surface temperatures of up to 7° higher than normal and salinity between 33 and $34^{o}/oo$ far south along the coast of Peru causing the strip of cool upwelling water to disappear. This phenomenon is called "El Niño".

(For general description of the hydrography of the area see Sverdrup et al. 1946, Wooster and Gilmartin 1961, Wyrtki 1963, 1966).

2.2 Effect of the current systems on the marine life

The upwelling along the Chilean and Peruvian coasts brings nutrient rich water to the surface and is the cause of an enormous growth of plankton on which in particular the huge school of anchoveta, but also many other pelagic animals and their predators depend. On the other hand, the Peru Undercurrent covers a very substantial part of the shelf area and the occurrence and abundance of species on which a demersal fishery can exist will thus be related with their ability to live in an environment of low oxygen content.

If the "El Niño" phenomenon occurs, both the distribution of the organisms in the coastal area and their abundance are affected. Many organisms from plankton to fish die, whereas others may migrate from the area or withdraw to deeper and cooler water. This makes the fish inaccessible to the guano birds, which in their turn die or migrate. Although dead fish may cover the beaches, the effect of "El Niño" on the magnitude of the resources is not really known. The inshore movement of warm and saline water by the coastal swirls described above also has considerable variation, and when it shows a greater development it has a similar effect to that of "El Niño", though very much milder.

3. PRIMARY PRODUCTION

Due to the upwelling along the Peru Current, the primary production in the area is high. Guillén and Izaguirre (1968) gave an average of around 190 gC/m^2/year. Strickland, Eppley and Rojas de Mendiola (1969) estimated the annual production near the coast of Peru at more than 200 gC/m^2, but suspect that it is considerably greater, possibly of the order of 500 gC/m^2. Cushing (1969) reviewed the available data on production in the upwelling areas in the world. He estimated the total carbon fixation in the Peru Current upwelling area (an area of approximately 1 x 10^6 km) at 155 x 10^6 tons C/year, of which about 45 x 10^6 tons were estimated to be produced off Chile and the remainder off the coast of Peru. This is lower than the estimated fixation in the Benguela Current upwelling of 278 x 10^6 tons C/year, but several times the estimated figure for any other upwelling area of the world. Rather different figures have been obtained by other authors, depending on the length and especially width assumed for the area of high productivity, e.g. Ryther (1969) used a width of only 50 km, rather than Cushing's values of up to 400 km, and thus obtained a much lower figure. More recent studies have shown that there is very much small scale variation in the upwelling process, which may have to be taken into account in obtaining more precise estimates of total primary production (Strickland, Eppley and Rojas de Mendiola 1969).

Outside the upwelling areas the estimates of primary production are much lower. Forsbergh and Joseph (1969) give observations which show that whereas in the upwelling areas the carbon fixation was generally over 45 mgC/m^3/day and varying up to occasionally 200 mgC/m^3/day, the observations at more than 100 km offshore are generally below 15 mgC/m^3/day and at more than 500 km offshore mostly below 5 mgC/m^3/day.

4. ZOOPLANKTON PRODUCTION

A substantial number of hauls for zooplankton have been made in the area of the Peru Current but have not yet all been worked up, or published. On the basis of available observations, (Flores 1967, Guillen and Flores 1967), Cushing (1969) estimated the standing stock in terms of carbon content in the different upwelling areas off Peru and Chile as ranging between, on the average, 2.5 and 8.5 gC/m^2, and the production as 16-21 x 10^6 tons C/year, of which somewhat less than half is produced off Chile and somewhat more than half off Peru. As for the hydrography and primary production, studies now in progress suggest a high degree of moderate to small scale variation in zooplankton abundance. When the results of these studies are published it will be possible to make much better estimates of standing stock and of production.

5. THE FISH AND THE FISHERIES

5.1 Statistics

Reasonably good statistics of total catch are available of the landings from this area (see Appendix Table L1). With the exception of tuna, practically all the fish landed from this area is caught by vessels of the two coastal countries. Effort data are available for the most important fisheries, although often for the most recent years only. Data on the location of the catches are lacking, but most fishing trips are of relatively short duration and thus the catches mainly derive from the area fairly close to the ports of landing. Except for the huge anchoveta fishery, and to some extent, the hake and bonito fishery, most of the other fisheries are still at artisanal level. For the latter fisheries species breakdown of the catch is not always possible and effort data are mostly limited to the number of vessels.

5.2 The fisheries

By far the major fishery in the area is that for anchoveta (*Engraulis ringens*), carried out along the whole coast of Peru and the extreme northern part of Chile, which started to develop in the second half of the fifties and reached a high level already in the early sixties. Other important fisheries are those for sardines (*Clupea*) in central Chile, for tuna-like fish (tuna, bonito) in Peru and northern Chile, and a trawl fishery for hake (*Merluccius*) off central Chile. Shrimp fisheries in Peru, and Chile, and molluscs in Chile are also valuable. Smaller fisheries include those for mackerel-type fish, jack mackerel, machete, dogfish, crabs, and several minor species such as croakers, congrios, and others. A fishery for hake is developing off northern Peru. The fisheries for tunas, crustaceans and molluscs are discussed in more detail in the relevant chapters which deal with these resources on a world basis.

5.3 Stock evaluation

5.3.1 Anchoveta (*Engraulis ringens*)

In terms of volume the Peruvian anchoveta fishery is by far the biggest single species fishery in the world. This seems to be due to a variety of reasons - the high productivity of the region, the fact that the anchoveta has no competitors of comparable abundance, and that it comes very early in the food chain. Though at some times of year adults feed heavily on zooplankton, as do young anchoveta, at other times the adults feed wholly or mainly on phytoplankton (Rojas de Mendiola *et al.* 1969).

Data on the anchoveta fishery have been collected by the national research institutes nearly from the beginning of the development of this fishery, and several papers studying the state of these stocks have been published (Murphy 1967, Boerema *et al.* 1965, Schaefer 1967, Gulland 1968, internal reports UNDP/FAO Fisheries Project Chile). Summary statistics are set out in Table L1 below. The general consensus of these studies is that the anchoveta stocks are near to being fully exploited. The latest studies of the Instituto del Mar in Peru (1969) indicate that the sustainable yield of the stock along the Peruvian coast is, on the average, between 8.5 and 9 million tons, with fluctuations around this figure due to the variations in such things as recruitment, and consumption by birds. This fishery is now regulated by a system of closed seasons and annual quotas. The latter are set taking into account the estimates of the recruitment level, and accordingly the recorded catches in seasons 1967/8 and 1968/9 reached a level of 10 million tons.

The system of recording catches in Peru under-estimates the quantity landed of the small fish. Making allowance for this, and applying these corrections to the yield estimate, it is likely that the average sustainable yield, as well as the actual catches in the last years before the 1967/8 season, are at a level of between 10 and 11 million tons. The actual catches in the last two seasons may have surpassed 12 million tons.

The catches of anchoveta in northern Chile have fluctuated in recent years between 0.5 and 1 million tons, independent of the fishing effort. It seems likely that these fish belong to the same stock as those in southern Peru, and that catch fluctuations are due to variations in distribution and availability. It is believed that further effort would not appreciably increase these catches, and hence that the present figures indicate the approximate maximum sustainable yield.

Table L1 - Summary statistics of Peruvian anchoveta fishery (catch in '000 tons, effort in '000 GRT-trips, corrected for efficiency)

Year	All countries			North			Central			South		
	Catch	Effort	c.p.u.e.	Catch	Effort	c.p.u.e.	Catch	Effort	c.p.u.e.	Catch	Effort	c.p.u.e.
1955(a)	59	(b)		(a)								
1956(a)	119	(b)		(a)								
1957(a)	326	(b)		(a)								
1958(a)	737	(b)		(a)								
1959(b)	1,908	(b)		689			1,159			59		
1960(b)	2,943	(b)		885			1,944			113		
1961	4,579	7,745	0.591	1,444	2,553	0.566	2,971	4,912	0.605	164	280	0.586
1962	6,274	10,746	0.584	2,193	3,272	0.670	3,800	6,910	0.550	281	563	0.499
1963	6,423	16,830	0.382	1,907	4,682	0.407	4,095	11,183	0.366	419	964	0.435
1964	8,863	21,695	0.409	3,429	7,086	0.484	4,649	12,775	0.364	785	1,833	0.428
1965	7,233	21,986	0.329	2,289	6,918	0.331	4,346	13,052	0.333	597	2,010	0.297
1966	8,523	20,148	0.423	2,897	6,369	0.455	4,719	12,517	0.377	905	1,931	0.469
1967	9,824	20,948	0.469	3,837	7,393	0.519	5,477	12,420	0.441	509	1,164	0.438
1968	10,106	21,232	0.476	4,350	8,548	0.509	5,097	11,428	0.446	658	1,327	0.496

Notes - (a) Data by regions not available
(b) Effort data not available

Accordingly, the total average sustainable yield of the anchoveta stocks off Peru and northern Chile is estimated at about 11 million tons. The fishery is managed in such a way that this is the average catch actually obtained. Some increases in the sustainable yield might still be possible if the catch of the very small fish could be avoided. Gulland (1968) estimates that the rate of exploitation, E, is probably a little less than 0.5 (i.e. the fishing mortality rate is slightly less than the natural mortality rate), from which it would follow that the present average total annual production would be of the order of 20-25 million tons and the natural mortality between 10 and 15 million. Part of this mortality is due to predation by the guano birds. Jordán and Fuentes (1966) estimate that the quantity of anchoveta eaten by the average population of birds (15-20 million) is of the order of 2.5 million tons, and thus between one quarter, and one sixth of the total natural deaths, but recently the population and consumption of birds has been lower.

The predation by the birds will affect the commercial catches, but it is not clear to what extent reduction of the bird predation would lead to an increase of the quantity of fish available to the fishermen (Gulland 1968).

Outside the area presently exploited, anchoveta is observed further south along the Chilean coast, in very much smaller quantities, however, than in the areas discussed above. These quantities will therefore not significantly affect the total estimates. Furthermore, in these areas some anchoveta is caught mixed with sardine and will thus be included in the sardine estimates. In the same way, the anchoveta estimates in northern Chile may contain an admixture of other species.

5.3.2 Hake (*Merluccius gayi*)

Two distinct areas of distribution of hake are found in the region, off central Chile, while it is exploited mainly between about 30° and 37°S but extends south to over 40°S, and off northern Peru, between about 4° and 8°S. Between these two main areas, small quantities are found at several places all along the coast.

The hake stocks off Chile have been exploited at a fairly constant level from about 1955 till the early sixties, with the catches fluctuating between 70 and 80,000 tons. From 1961 the catches rose to over 100,000 tons in 1963 and 1965 (with a fall in the landings to 73,000 tons in 1964, possibly due to low availability of the fish in that year), and declining thereafter to 80,000 tons in 1967. Saetersdal and Avilés (1968) analyzed the fishery in the period 1960-6. In this period the effort did not change greatly until 1964-5, when a substantial increase took place. The available data suggest that the increase in effort was accompanied by a substantial decrease in the catch per unit effort, but the effort estimates are very rough only, and further data are needed to obtain a quantitative estimate of this effect. Saetersdal and Villegas (1968) mention that in the area off Valparaiso the relative proportion of large hake has decreased considerably in recent years as compared with 1958-9.

Tagging experiments of large fish with external tags have shown a recovery rate of about 9% in the year after tagging (Saetersdal and Villegas 1968). The recovery rate of the trawl fishery, which accounts for 90-95% of the landing, was, however, much lower than that of the handline fishery, per ton of hake caught, which indicates that many of the tagged fish caught in the trawl fishery have not been discovered, partly due to the fact that about 70% of this catch is used for fish meal. More recent figures from the Chilean Instituto de Fomento Pesquero show that of 3,800 tagged fish, 140 were returned within 3 months, which extrapolated, would mean a return rate of about 16% per year. Detailed analysis has suggested a high rate of tag loss. Taking into account the inevitable effects of tagging mortality, tag losses, and losses in recovering and reporting of tags, these figures indicate a substantial fishing mortality.

Saetersdal and Villegas (1968) mention that differences in growth, size compositions and sex: size ratios suggest that the mixing of the hake stocks along the coast is incomplete. On the other hand the tagging experiments have shown that the hake migrates over long distances, up to 400 km, probably related with spawning and growth, and it may well be that in effect the whole population is exploited.

No detailed assessments are as yet available. The information given above indicates, however, that the fishery takes an appreciable fraction of the stocks, and could already be fairly close to the optimum potential. Further analyses are in progress at the Chilean Institute. For the time being the average potential of the stocks can perhaps be estimated at, say 120,000 tons. Including the areas where merlusa is present in small quantities along the coast, this might bring up the total to 130,000 tons.

The hake stocks off northern Peru have until recently been only very lightly exploited. In 1966 the landings reached 10,000 tons and in 1967 20,000 tons. Exploratory fishing by foreign research vessels, and experimental and exploratory cruises with commercial vessels had indicated the occurrence of large schools of hake in the area. Recent acoustic surveys, combined with fishing, carried out by the Peruvian Instituto del Mar, showed that the hake is mainly concentrated over a distance of roughly 250 km along the coast, and between the depth contours of 100 and 300 m. in water with an oxygen content of around 1-2 ml/l (Instituto del Mar 1969). (Similar observations in Chile showed that in that area the major concentrations are often found between depths of 100 and 200 m, at an oxygen content of between 0.6 and over 1 ml/l (Instituto de Fomento Pesquero 1968). Echo records were obtained showing concentrations of over 1,000 fish/n.mi which are estimated to be rather higher concentration than those observed by Cushing on the Atlantic coast off south and southwest Africa (Midttun 1969, Cushing 1968). No detailed comparison is presently available, but as a first estimate and taking into account that the stocks off Africa were already rather intensively exploited at the time of the survey, it could be assumed that the average potential per unit surface is approximately similar in these two areas or maybe somewhat greater in Peru. The area of distribution off northern Peru is perhaps somewhat less than one tenth that of south and southwest Africa. The hake potential in the latter area is estimated at 500,000 tons, and on this basis the potential off northern Peru would be of the order of, say, 60,000 tons. Noting that the main hake area off northern Peru extends along the coast over a distance equal to about half the distance covered by the main hake grounds off central Chile, and assuming that the Peru potential per unit area would also be similar to that off Chile, a figure of the same order would be obtained.

No data on catch per unit effort of the commercial hake fishery off northern Peru have as yet been published, but the relevant data are at present being collected and analysed at the national fisheries institute. Some data on catch rates from exploratory vessels are available, but are difficult to compare with those of other regions, due to the different methods and gears used.

Thus, the potential of the resources of hake (Merluccius gayi) in the whole area under consideration would probably be of the order of 200,000 tons.

5.3.3 Bonito (Sarda chiliensis and S. velox)

Two species of bonito are caught in the area, Sarda chiliensis and S. velox. S. velox seems to reach the southern limit of its distribution off northern Peru, whereas S. chiliensis extends along the Peruvian and Chilean coasts to about 35°S. No distinction is made between the two species in the data of the commercial landings, and the proportion of each species in the total landings is unknown.

The landings in Peru have fluctuated between 60 and 75,000 tons in the last seven or eight years (the rather higher figures for the earlier years of this period published in the official statistics of around 100,000 tons around 1969, may have been over-estimates. Revised figures have been collected by the Instituto del Mar). The total effort in this period is estimated to have remained fairly constant.

The landings in Chile increased in recent years from a few thousand tons to a peak level of 12,800 tons in 1966, but have since decreased to 4,100 in 1968, although fishing effort has continued to increase.

Bonito concentrations are often found associated with the anchoveta*. There is substantial seasonal variation in the catches, probably related with the migration pattern of the fish. The fluctuations in the annual catches are thought to have been due to variations in migration and availability.

No data on the extent of the stocks, the size and age distribution of the landings, etc., are as yet available. It is possible that the stocks are already rather heavily exploited, and that the present yield is not very much below the optimum potential.

No estimate of the potential of these stocks can at present be made, other than stating that it must be at least as high as the present average catch of roughly 80,000 tons, and is likely to be higher.

5.3.4 Common sardine (Clupea bentincki)

This species is found along the Chilean coast between about 30° and 40°S. The records on which the official statistics are based do not always clearly distinguish between the various clupeoid species and often include mixed landings under one heading, and therefore the published statistics are not reliable for the individual species. Figures collected by the Chilean Instituto de Fomento Pesquero show that the fishery for this species has developed rapidly in recent years from about 20,000 tons in 1963 to over 80,000 tons in 1967, mainly caught in the Arauco Bay at about 37°S. Small quantities are landed annually in ports further north along the coast.

Such explorations as have been carried out up till the present have not yet shown the existence of substantial concentrations outside the Arauco Bay. It seems unlikely, however, that the species is practically limited to this bay. No assessments of the sardine fishery in the bay are available, and it is possible that here also the catch can be increased further. It is not possible, on the basis of the available information, to make any assessment, but it does not seem unreasonable to assume that the production of this species could at least be doubled.

5.3.5 Other species (demersal)

Both in the commercial trawl fishery, and in the artisanal fisheries of different types, a large variety of species of demersal fish is caught. No assessments of any kind are available, and even the total landing statistics may not be very reliable in their details of these species.

Exploratory cruises have provided some information of the species composition and the distribution on the trawlable fishing grounds, in particular off northern Peru and central Chile.

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de Vildoso (1963) suggests that the area of distribution is limited to the coasts of Peru and Chile, where most of the catches are made within 30 ml offshore.

For the area off northern Peru, recent cruises combining acoustic surveys with trawling have provided some quantitative estimates for that area, approximately between 3° and 9°S. The species composition varied within this area, consisting predominantly of hake in the southern and of other species in the northern part, mainly tollo (Mustelus sp.), cabrilla (Paralabrax sp.), doncella (Hemanthias sp.), and in the northermost part of the area bereche (Ctenosciaena). In the whole of the area, hake formed about 70% and the other species 30% of the catch. If this proportion would also apply to the catch potential, the estimate of the catch potential of hake of 60,000 tons would give an estimate of 25,000 tons for the other demersal fish in this area, and a figure of yield of all demersal fish of about 20 kg/ha.

The shelf area north of 9°S covers somewhat less than half the shelf area of the Peruvian coast. Few explorations for demersal fish have as yet been carried out in this area south of 9°S. In 1965 young hake, smaller than 25 cm, was found up to about 14°S (del Solar, Sánchez and Piazza 1965), and small concentrations of hake have been encountered in the southern part on other occasions. Explorations carried out recently indicated that the abundance of demersal fish south of 9°S, until the Chilean border, was considerably lower than in the northern area, due to the general absence of hake. The species composition of the other fish was somewhat different from that in the north, but the data are insufficient for more detailed comparison (Jordán and Villanueva 1969, Fuentes, Mesia and Samamé 1969). As a first estimate, it could therefore be taken that the abundance of demersal fish along the Peruvian coast south of 9°S is about equal to that of the demersal fish, excluding the hake, in the northern part, and the catch potential would therefore provisionally be taken as being also of the order of 25,000 tons. This would give a total estimate of 50,000 tons for the catch potential of all demersal fish other than hake, along the whole Peruvian coast.

In the area off the Chilean coast, a number of exploratory cruises have been carried out in the area between about 30° and 40°S (Vestnes, Strom, and Villegas 1965; Vestnes et al. 1965, 1966; Mistakidis and Henriquez 1966; Instituto de Fomento Pesquero 1968, 1968a). During these cruises echo sounders were used and exploratory trawl hauls made. On the average, the catches consisted for about 80% of the hake and for 20% of other demersal fish (crustaceae have been excluded in these calculations). Main species in the "other fish" were peje-gallo (Callorhynchus callorhynchus) merluza de cola (Macruronus magellanicus, caught especially in the southernmost part of the area), peje-rata (various Macrurids), cabrilla (Sebastodes spp.), lenguado (Paralichthys spp.), besugo (Epigonus sp.). Further south, recent exploratory fishing has given occasional good catches (up to 16 tons) of Macruronus (Instituto de Fomento Pesquero, unpublished information). Again assuming that the proportion of hake and other fish would also apply to the catch potential, and that the hake potential in this area is 120,000 tons, the potential of other demersal fish in this area would be of the order of 30,000 tons, and the total potential yield per ha would be of the order of 25 kg.

The area north of 30°S until the Peruvian border seems to be less suitable for trawling, and has a fairly narrow shelf. South of about 45°S, and up to at least 51°S, it also seems that in general the bottom is not suitable for trawling, but insufficient explorations have been carried out. Some observations with long-lines showed that good catches of congrio (Genypterus sp.) can be made in the southern area. A few exploratory surveys have been carried out in the area between 40° and 45°S, in which the trawl catch per hour of fish other than Gadoids was of roughly the same order of magnitude as that in the area between 30° and 40°S (Stroem et al. 1966; Villegas, Trujillo, and Löhre 1967). For the area south of 45°S practically nothing is known, except for the Chilean king crab (Lithodes antarctica), which is caught mainly around the Strait of Magellan.

If it is assumed that the density of demersal fish other than Gadoids on the whole of the southern and northern parts of the shelf area off Chile is about the same as that of the area between 30° and 40°S, even though the species composition will be different, and noting that the total shelf area is about 5 times that between 30° and 40°S, a very rough first estimate of the catch potential of this fish along the whole Chilean coast would be of the order of 150,000 tons.

Two species of Gadoids are found in appreciable quantities south of about 40°S, the southern hake (Merluccius polylepis) and the grenadier (merluza de cola, Macruronus magellanicus). Only the first of the two species is exploited in very small quantities, from one of the local ports in the area. A few exploratory cruises between 40° and 45°S gave average catch rates which were for southern hake about one eighth of the catch rate of Merluccius gayi between 30° and 40°S, and for the grenadier somewhat more than half that of M. gayi. Nothing is known of their abundance further south, nor of the southern limit of their distribution. Taking into account the magnitude of the southern shelf area, which is more than three times that between 30° and 40°S, it seems reasonable to assume that the potential of these two species together is at least equal to that of M. gayi, and probably higher. A first guess might be of the order of 200,000 tons.

5.3.5 Other species (pelagic)

Clupeoids not discussed in the previous sections include Clupea fuegensis, possibly present in substantial quantities along the southernmost part of the Chilean coast, Sardinops sagax, off northern Chile and Peru, and machuelo and machete (Ethmidium spp.) also off northern Chile and Peru. Of these, C. fuengensis is hardly exploited, the catches of S. sagax amounted to about 10,000 tons, mainly in Chile, and of the Ethmidium spp. to about 20,000 tons in 1967, mainly in Peru. Nothing is known about the magnitude of these resources. Investigations on S. sagax are in progress. Whereas it could be that the stocks of S. sagax, and of Ethmidium are not very large, those of C. fuegensis might well be extensive, taking into acount their distribution along the Chilean coast from about 45°S southward, with its many bays and islands. In the absence of any further data a first guess of 200,000 tons potential yield for the three species together might be acceptable (see for S. sagax also the section on eggs and larvae).

Mackerel type fish, in particular sierra (Thyrsites and Thyrsitops) in Chile and caballa (Pneumatophorus peruanus) in Peru has been caught at a level of a total quantity of about 20,000 tons in the last years, with increasing catches in Peru and decreasing ones in Chile. Jack mackerel, in particular jurel (Trachurus murphyi) in Chile and jurel and cojinoba (Neptomenus crassus) in Peru, have been caught in increasing quantities in recent years, with a total for both countries of about 26,000 tons in 1965 rising to 43,000 tons in 1966. Observations in other upwelling areas (southwest Africa, California, see the relevant area chapters) have indicated a potential yield for jack mackerels which is several times that of mackerel-type fish. If the same would apply to the stocks off Chile and Peru, this would mean that at least the potential yield of jack mackerels is considerably higher than the present catch. It is probable that also the yield for mackerel-type fish is higher than the present catch; but no data from catches or exploratory surveys are available on which to base any estimate. The only indication that the stocks may not be extremely large might come from the fact that from the acoustic and exploratory fishing surveys no substantial quantities of these species have been reported so far. The available data indicate that the potential catch of mackerel-type fish and jack mackerels together would be at least 100,000 tons, and comparison with other similar areas would suggest that it might be several times that figure.

5.3.6 Squid

Squid has been landed in very small quantities, varying between less than one thousand and a few thousand tons, in the last ten years. The landings include both jibia (Ommastrephes) and calamar (Loligo spp.). Acoustic and other observations, including exploratory fishing, have shown, however, that the abundance, especially of Ommastrephes, is considerable in the same area in which anchoveta is concentrated (Midttun 1969) although no quantitative data are as yet available. Occasional observations of stomach contents showed a very high proportion of anchoveta in the food. Total natural, non-fishing, deaths of anchovy have been estimated as 10-15 million tons. Of this up to 2.5 million tons is eaten by birds, so that other consumers eat rather over 10 million tons; if these have a 10% to 15% conversion efficiency, then the annual production of these predators would be around 1 to 1.5 million tons, much of which might be expected to be squid.

Another estimate can be obtained by a similar method, from the opposite direction. Squid (Ommastrephes) are the major food of the sperm whale. The average meal estimated by Peruvian scientists is approximately 80 kg. If this is the daily consumption, and there are some 50,000 sperm whales (about 10 times the annual catch around 1960) in the area, the total annual consumption is 80 x 365 x 50,000 kg = 1.46 million tons. Since not all squid are eaten by whales, this figure is rather high compared with the estimate from predation on anchovies. However, in relation to their rough nature, the agreement between the figures is quite reasonable. They suggest an annual production of squid of around 1 million tons, of which perhaps half could be harvested.

5.4 Micronekton

Blackburn (1968) summarised the data on the abundance of micronekton (animals between 1 and 10 cm in greatest dimension) on the Pacific coast of America between about 35°N and 25°S, obtained from hauls with a special net from a depth of about 90 m to the surface. He mentions that the catches do not seem to be representative for the abundance of active epi-pelagic fish such as scombrids, carangids and others, but estimates that Myctophidae, the largest fish component in the catches in most areas, is much better represented. Myctophids are fairly evenly distributed in the area from north to south with some decline in the abundance from the coastal area to farther offshore. No quantitative data are available for the area south of 25°S, but Stroem et al. (1966) and Villegas , Trujillo, and Löhre (1967) mention the occurrence of substantial quantities of myctophids in the area off Chile, at about 42°S. If it is assumed that the abundance along the whole coast of the area under review is similar to that in the sampled area, a rough estimate of the standing crop of this fish can be made. The average catch of myctophids obtained by Blackburn within 300 mi from the coast was 3.6 ml per 1,000 m^3 seawater. The area from 5°S till Cape Horn is 3,000 x 300 mi or 3 x 10^6 km^2, which to a depth of 90 m means 270 x $10^{12}m^3$. The volume of the standing crop of myctophids would thus be 3.6 x 270 x 10^9 ml, or roughly 1 x 10^9 l, equal to about 1 million tons. It should be noted that, apart from other uncertainties in this estimate, the possibility of part of the fish escaping in front of the net would make this figure an under-estimate. The natural mortality of these small fish is likely to be high. The potential yield might be of the order of a few hundreds of thousands of tons.

5.5 Eggs and larvae

Some larvae of saury (Scomberesox sp.) have been reported from the area (Rojas de Mendiola 1969). Ahlstrom (in Eastropac Information Paper No. 10) suggests that Scomberesox must be one of the large potential fish resources off Chile.

Series of egg and larvae cruises have been carried out in the areas along the Peruvian coast and off northern Chile. Einarsson et al. (1966) summarised the data collected between August 1961 and May 1964 for the Peruvian area north of Callao (11°S). They found that the number of eggs and larvae of species other than anchoveta amounted to between 4 and 25% (average roughly 15%) of the quantity of anchoveta eggs and larvae, except in autumn when the numbers for all species were low. In order to be able to use numbers of eggs as a rough indicator of the relative abundance of various species, data must be known on the life-span of the eggs of those species, the egg production per unit stock weight, etc. Very little is known about these characteristics for most of the species in the region, but data from Miñano (1968) and Fischer (personal communication) suggest that the egg production per 1,000 gr anchoveta of average size is about double that of hake of average size. Against this, the duration of the egg stage in anchoveta is believed to be quite short, possibly shorter than for most other species. Thus one rough estimate of the total standing stock of other fish in the area is 15% of that of the anchoveta.

The potential yield of anchoveta in the Peruvian area was estimated at about 10 million tons, and of the other fish of roughly 500,000 tons, or 5% of the anchoveta. Taking into account that many of the stocks other than anchoveta are lightly or not exploited and thus are relatively abundant as compared with their numbers at optimum exploitation, that the egg catches may contain substantial numbers of small and at present unexploitable fish species, and that several other factors may distort the picture, the above considerations suggest that the estimates obtained in this document for the potential yield of the fish species other than anchoveta in the Peruvian area are reasonable, but might if anything be an under-estimate. The latter would fit in with two observations. First, it is believed that the stocks of jack mackerel might well be quite substantial. Second, the potential catch of demersal fish, other than hake in the Peruvian area, has been estimated at 50,000 tons, and the actual catch in 1967 amounted to about 45,000 tons. It is however, not likely that the present demersal fishery is already so close to the optimum, and thus the figure given for the potential is likely to be an under-estimate, even though it is probably true that this fishery cannot be very greatly extended, apart from the hake fishery.

Brandhorst et al. (1965) and Brandhorst and Rojas (1968) reported on some egg and larvae cruises off northern Chile, between 18° and 25°S. They found that the numbers of eggs and of larvae of Sardinops sagax, the Spanish sardine, were about 5% those of anchoveta. For all other fish species, numbers of eggs were about 20% those of anchoveta; numbers of larvae varied between somewhat more than half, and double those of anchoveta. Even though the number of cruises was small and the timing may have influenced the results, these data seem to confirm the suggestion made before that the stocks of Sardinops sagax are not very large, with a potential yield of perhaps a few tens of thousands of tons in this area. For the other fish species, the data of eggs and larvae are not very consistent, but suggest, as in the case of Peru, that the other fish species in the area may have been under-estimated. Because the area between 18°and 25°S has a very narrow shelf, the fish concerned are probably pelagic. This would fit in with the observation made before that the stocks of jack mackerel might be substantial.

6. DISCUSSION AND SUMMARY

Table L2 summarises the estimates of potential yields arrived at in this review. It should be stated again that all estimates except those for anchoveta have been based on very little information, and should be considered only as first attempts to obtain an idea of the order of magnitude of these yields. The national fisheries institutes in Chile and Peru have collected a substantial amount of information on various fish species, and analyses of the data are in progress. It will, therefore, soon be possible to improve several of the present estimates.

Table L2 - Estimates of potential yield (in '000 tons) in the Southeast Pacific

Species	Peru	Chile	TOTAL
Pelagic			
Anchoveta	10,000	1,000	11,000
Common sardine (C. bentincki)	-	160	160
Other clupeoids			200
Bonito			> 80
Other pelagic (excluding Myctophids, etc.)			? x 100
TOTAL			>11,600
Demersal			
Hake (M. gayi)	60	130	190
Other Gadoids	-	200	200
Other demersal	> 50	150	200
TOTAL			590
Squid			500
Myctophids and other similar fish			500
GRAND TOTAL			

Note - - Information zero

Table L2 also shows that anchoveta not only is the present major species in the catches, but that the potential of all other species together is estimated to be far less than the anchoveta potential. The potential of anchoveta may be compared with the total primary production. As mentioned earlier the estimate of the latter will depend on the assumed extent of the zone of high production. Off Peru this is around 2,000 km long, and perhaps the width of the area relevant to anchoveta production is 100 km wide. If the production in this band averages 200 gC/m^2/year (possibly higher in the centre, the annual carbon fixation is 40 million tons. The wet weight production of herbivores will be about the same, if efficiency is around 10-15%, and, at the same efficiency, the annual production of primary carnivores would be around 5 million tons. The estimated production of anchoveta falls between the two figures, which gives fair agreement, since anchoveta eat a mixture of zooplankton and phytoplankton (Rojas de Mendiola et al. 1969).

The estimates of the potential yield of demersal fish per ha, 20 kg for Peru and 25 kg for central Chile, seem relatively low in comparison with the general productivity of the area. The figures may be under-estimated, but it is also possible that the low oxygen content of the water over a large part of the shelf north of 40°S limits the magnitude of the standing stock in this region. The estimate for the whole area is even lower, 16 kg/ha, due to conservative extrapolation of the figures of the other areas to the large shelf area off southern Chile for which practically no data exist.

The total potential of 13 million tons makes the area one of the major areas in the world.

It should be noted that the estimate of the potential of the various species would not necessarily mean that these quantities could be harvested economically. Some species may, for instance, have a relatively high total potential but may be spread so thinly that it is not worth fishing with present methods. An extreme case is that of the Myctophids. Development of the techniques for harvesting these fishes has hardly started. In other cases exploitation at the level of optimum potential yield might require an excessively high fishing effort and exploitation at a somewhat lower level would be more reasonable.

7. REQUIREMENTS FOR FURTHER RESEARCH

It has been made clear in the previous sections that the available data were in nearly all cases inadequate, and that the estimates given, except for anchoveta, are at best rather rough and often only reasoned guesses.

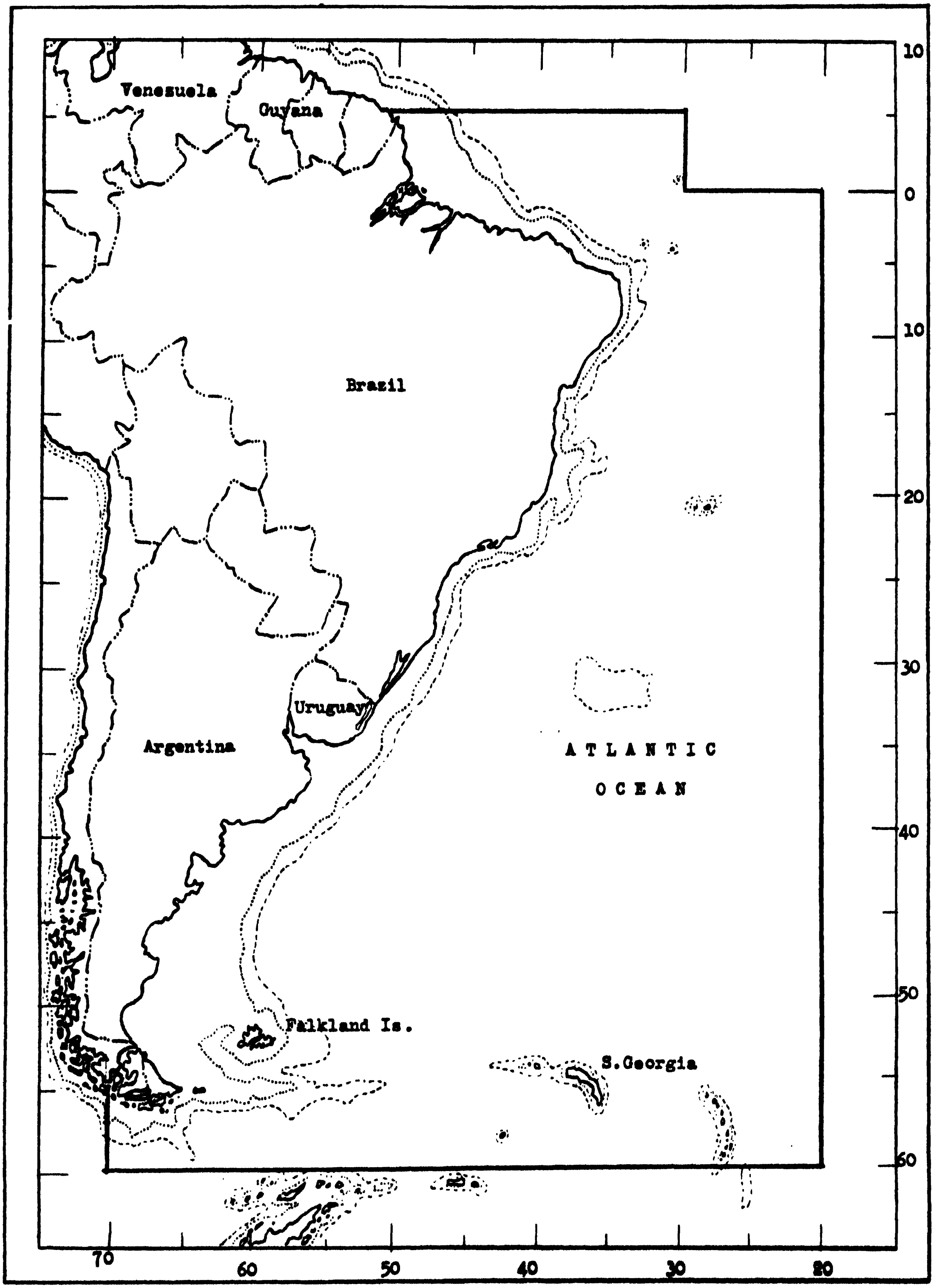
Investigations are in progress, and more reliable data will be forthcoming but it may be useful to point out some specific subjects on which more detailed information would be especially helpful to improve the estimates of all species other than anchoveta.

The statistics of the landings could in many cases be improved, and there is particular need for information on effort and/or catch per unit of effort.

Published data on exploratory surveys have not always included full quantitative details. Further cruises, using acoustic methods, and standardized fishing gear of various kinds, would be useful for nearly all areas to obtain estimates of relative abundance of the species, and the quantitative data should be summarised. For some of the least-known areas, such as off southern Chile, any information from exploratory cruises would be of value.

A substantial amount of egg and larvae cruises have been carried out, usually in the context of the anchoveta investigations. Identification of the eggs and larvae of other species or species groups in the existing plankton collection, and summarizing all the existing data, would be valuable to obtain better estimates of the relative abundance and perhaps first estimates of the absolute abundance of these species and groups.

Stock assessments by the established methods should start for the major exploited species as soon as sufficient data on catch and effort, on length and age composition in the landings, etc., have been obtained.



M - SOUTHWEST ATLANTIC

Depth contours at 200 and 2,000 m

1. TOPOGRAPHY

The western limits of the Southwest Atlantic area are the coasts of Brasil, Uruguay and Argentina, to 70°W at the southern extremity; the eastern boundary (20°W) is close to the western slope of the mid-Atlantic Ridge. The northern delineation (at 5°N) follows the Equatorial Counter Current; the southern boundary (60°S) is the Antarctic Convergence.

The shelf along the South American coast measures 2.1 x 10^6 km^2 (see Table M1).

Table M1 - Areas of shelf and slope in the Southwest Atlantic ('000 km^2) (from Moiseev 1969, Table 16)

Area	Shelf (0-200 m)	Slope	
		200-1,000 m	1,000-2,000 m
Guyanan	160	30	50
Brasilian	610	200	180
Uruguayan	150	20	20
Argentinean-Falkland	1,030	200	240
TOTAL	1,940	450	490

The shelf on the north coast of Brasil is rocky and coralline except in the area of the Amazon where river deposits with much trash prevail. In most of the northern area trawling seems very difficult. The central and south Brasilian coast is rocky and coralline in the northern part; along the southernmost coast of Brasil, the ground is more easily trawlable - there are, however, offshore bars. On the Patagonian Shelf, which is the largest shelf area of the southern hemisphere, there are good trawling grounds in the bays of La Plata estuary and Bahia Blanca, San Matias and San Jorge. South of 42°N the bottom becomes increasingly rough but is still trawlable. Burdwood Bank again has some good ground for trawling, but large stones are frequent (Matthews 1934). The depth of the shelf is less than 50 m in most areas except in the offshore parts of northern Brazil and on the Falkland Shelf. It is very shallow in the La Plata Bay. The slope is steep in the northern part of the Patagonian Shelf, but more gentle in the south. It is trawlable in most parts of the area.

Two oceanic basins of almost 6,000 m depth (Brazil Basin and Argentina Basin) are separated by the Rio Grande Ridge (minimum depth 600 m).

2. HYDROGRAPHY

The shelf areas are influenced by the warm Brasil Current, an off-shoot of the South Equatorial Current turning to the south and by the cold Falkland Current which carries Antarctic water to the Patagonian-Argentinian Shelf. The latter can be traced along the coast up to Rio de Janeiro where it meets the Brasil Current which leaves the coast and moves southward some distance from the coast. In this area, a water mass of mixed origin and high fertility covers the shelf. At the boundary of the two currents, eddies and vertical transport of water masses have been observed. In the open ocean, the northern part is occupied by the westward South Equatorial Current and South Subtropical Current; the southern part is characterised by the Westwind Drift; the central part of the South Atlantic is an area of little water movement, the South Atlantic Eddy. At the Subtropical Convergence, which lies in the open ocean at about 40°S but bends northward off the Patagonian Shelf, surface temperature tends to fall rather sharply by about 4°C. The convergence is not stationary but shows considerable movements. The highest monthly mean surface temperature on the Patagonian Shelf in summer ranges from ca 6°C off Tierra del Fuego and Falkland Island to ca 22°C off Rio de la Plata. The lowest monthly means in winter range from ca 3°C to ca 15°C. The shelf area proper is slightly warmer than the surface water in the area of the slope as there is a tongue of cold water extending northward some distance from the coast. In the open ocean again water temperatures tend to be higher (Neumann 1965, Emilsson 1961, Deacon 1965).

Along most parts of the Brasilian coast, water temperatures are high all the year round, with maximum temperatures off the Amazon mouth, where even the lowest monthly mean is above 27°C. Off Rio de Janeiro, monthly means reach 26°C in summer and 21°C in winter.

3. PRIMARY PRODUCTION

There are no summary reviews on primary production of the area. Teixeira and Tundisi (1967) worked a section from the mouth of the Amazon to the equatorial Atlantic. In March, they found very high values of carbon fixation (0.86 $gC/m^2/day$) on an inshore station, but only 0.048 $gC/m^2/day$ 240 mi off the coast and 0.014 $gC/m^2/day$ 480 mi off the coast. In the open ocean, much higher figures might be found in July/August. Volkovinsky (1966) found high primary production in the Falkland area (ca 50 $mgC/m^3/day$) - similar to those in the South Georgia region. Primary production decreases if one moves north but increases again in the estuary of Rio de la Plata (ca 130 $mgC/m^3/day$, but presumably in a very shallow euphotic zone).

El Sayed (1966) (and also El Sayed *et al.* 1964, El Sayed and Mandelli 1965) reported higher primary production off the Argentinean coast than in the Drake Passage and Weddell Sea. According to Mandelli and Orlando (1966), the Falkland Current is amongst the most productive area of the world oceans and also carries a permanent high phytoplankton biomass. At the slope from 37° to 52°S, measurements were taken on phytoplankton biomass (chlorophyll and primary production (C^{14} method)).

In the central area off Golfo San Matias total abundance of phytoplankton biomass was 110-120 mg/m^2 in September, the euphotic zone being 15-25 m. Further to the south values were less uniform and much lower; they were from 18-29 mg/m^2 in September and 32-40 mg/m^2 in November (Mandelli and Orlando 1966).

Primary production was 0.75-1.00 $gC/m^2/day$ in the central area but 0.05-0.55 $gC/m^2/day$ in the rest of the area. In November the corresponding values were 1.5-1.7 $gC/m^2/day$ and 0.14-1.3 $gC/m^2/day$.

From those figures, one might estimate that annual primary production in the Falkland Current is more than 200 gC/m^2 in the central part (about 40-44°S) and less than half as much in the southern parts.

4. ZOOPLANKTON AND INVERTEBRATE BENTHOS

There are no detailed reviews at hand on distribution and abundance of zooplankton and benthos in the area. Relevant data, particularly on plankton abundance are, however, contained in various publications, e.g. of the Instituto de Biologia Marina, Mar del Plata, and from Brasil (Vannucci and Queiros 1963), and also in expedition reports, such as METEOR South Atlantic Expeditions. Over the Patagonian Shelf the standing crop of zooplankton is moderately high (>100 mg/m^3), but decreases northwards to a level of 25-50 mg/m^3 off central Brasil - low for a shelf area. The benthos off Brasil has been discussed by Rowe (1969), who showed that it was scarce, though the abundance decreased less slowly in an offshore direction than in areas of higher productivity.

5. FISH STOCKS AND FISHERIES

5.1 The fisheries

(a) Brasil

Fishing along the northern and central coast is mainly pursued by small craft and sailing rafts using various types of seine nets, long-lines and traps. Along the southern coast and extending well onto the Patagonian Shelf considerable bottom trawling is done by larger vessels (Vassoler and Vassoler 1969). Sardine (sardinha), whose catches fluctuate markedly, croaker (particularly corvina) and hake (merlusa) are the most important species. Total marine catch in 1968 was reported as 340,000 tons - nearly three times the reported quantity in 1956. There is a growing fishery for shrimp in the Amazon region, though the shrimp fisheries off central and southern Brasil are no longer expanding.

(b) Uruguay

The fishery is carried out by bottom trawl on a rather small, but increasing scale. Reported landings in 1967 were some 10,000 tons, mainly various bottom fish - hakes (merluza), croaker (corvina blanca) and sciaenidae (pescadilla).

(c) Argentina

Total marine catch in 1968, 210,000 tons, has doubled since 1962. The main part of the catch is taken by trawlers of various sizes, though there is some lining and pair fishing. Off Argentina, the major winter fishing is for hake (merlusa) in the area 35-38°S. In summer, the centre of the fishery moves southward to 38-42°S. The exploitation of anchovy (anchoita) is concentrated in late winter and spring in the Mar del Plata area. As soon as mackerel invades the coast waters, the fishery is directed to the latter only (during summer, until end-March).

The utilisation in Argentina of the hawkfish (castañeta) (Cheilodactylus bergii) for fish meal increased greatly up to 1966 (68,000 tons) but fell to only 4,000 tons in 1968, possibly due to too heavy fishing. Very good catches of salmon de mar (Pinguipes spp.) are being obtained near Rawson (Patagonia), and possibilities of further expansion exist (Boschi and Mistakidis 1966). Shrimp catches, particularly of the langostino (Hymenopenalus mulleri), have been declining steadily in Argentina (Boschi and Mistakidis 1966). There are important fisheries for molluscs, especially mussels (Mytilus spp.) and seaweeds are also harvested.

(d) Long-range vessels

Fishing in the area had been almost entirely restricted until very recently to locally based vessels. Since about 1966, a number of European countries have become interested in trawling in the area, especially for hake. The biggest catches have been taken by USSR, which took over half a million tons of hake in 1967.

5.2 Statistics

The statistical information available is not entirely satisfactory. Species breakdown is given, but sometimes there are obvious inconsistencies from year to year. More detailed information on the area of capture, especially by the long-range vessels, and on fishing effort is required. These problems are being studied by a working party of CARPAS.

5.3 Stock assessments for exploited stocks

Few detailed assessments of any of the important pelagic or demersal stocks are available. Estimates of the stock of anchovy, based on egg data and echo surveys, are discussed below.

5.4 Indications for size of stocks

5.4.1 Species review

The most important species in terms of abundance are:

Engraulis anchoita - anchovy, anchoita
Clupea fuegensis - Falkland herring
Scomber japonicus marplatensis - mackerel
Sardinella aurita - sardine
Micropagon spp. - croaker (corvina)
Merluccius merluccius hubbsi - hake, merluza
Micromesistius australis - poutassou, polaca
Illex sp. - squid
Macruronus magellanicus - long tailed hake, merluza de cola

Sardines (Sardinella aurita)

The largest concentrations are off the central and southern coasts of Brasil (22°-29°S) (Moraes 1963). The major port of landing is Santos. Abundance varies both seasonally and annually. From the increase of catch with increasing effort (according to Moraes (1966), catch per unit effort has not decreased following the recent increase of effort) one might doubt earlier statements that the sardine catch had already reached its maximum. The southern population off Florianopolis in particular seems not to be fully exploited. The greatest catch in recent years was 88,000 tons in 1967, and this might be somewhat exceeded by improved searching. As, however, in some years, the number of dense schools seems rather small, it is not advisable to have a large fishing industry depending on sardines only. The average annual yield might, therefore, not much exceed the present level, say 100,000 tons.

Anchovy (Engraulis anchoita)

This species is distributed from north of Rio de la Plata to Golfo San Jorge. In winter dense concentrations have been found in the Golfo San Matias. The only exploitation is at present by small boats in the Mar del Plata region. Some exploratory fishing by pelagic trawl and echo surveys indicated very high abundance all over the shelf of northern and central Argentina. It is regarded as the biggest resource of the region. Estimates of standing stock have been made from echo surveys by Aasen (1968), as 2.1 million tons in June 1967 in the area between the Rio de la Plata and Bahia Blanca, and by Aasen and Castello (1968) as 1.2 million and 0.5 million tons in two spawning groups in November 1967, in much the same area.

From egg surveys, de Ciechomski and Boschi (1968) estimated the average density of spawning fish in 1966 as 50 tons/km^2. The total spawning area can be roughly estimated from the figures of de Ciechomski (1968) as 10,000 km^2, giving a total spawning biomass of 0.5 million tons.

Given the nature of the estimates, the agreement is reasonable, and suggests a biomass of the order of 1-2 million tons. The natural mortality of anchovy is high, say 1.0, which using the methods developed in the preface gives an estimate of potential of 0.5 x 1 x 1-2 = 0.5-1.0 million tons. Anchovy spends the first year of life in coastal waters, then lives for about half a year in the open sea until it returns to the coast in its second winter. The fishery could, therefore, be expanded both in area and in season.

Mackerel (*Scomber japonicus marplatensis*)

This species is taken by the same fishery as anchovy. As the fishing industry prefers mackerel, the ships concentrate on them as soon as they approach the coast. In summer mackerel moves from the open sea into Rio de la Plata, from there along the coast to Mar del Plata and Bahia Blanca, and then out again into open waters. The resource is probably much smaller than that of anchovy.

Falkland herring (*Clupea fuegensis*)

This is considered to be very abundant in the area between Tierra del Fuego and the Falkland Islands. Its distribution extends northward up to Golfo San Jorge. No detailed information on abundance and life history of the fish is available. The potential yield might be comparable to that of herring in the North Sea which has an area of distribution about the same extent as that of *Clupea fuegensis*. One might then expect an annual yield of 1-1.5 million tons. A comparative study of population dynamics of Falkland herring would be particularly interesting.

Hake (*Merluccius merluccius hubbsi*) and Poutassou (*Micromesistius australis*)

The area of distribution of *Merluccius merluccius hubbsi* is between Rio de la Plata and about 45°S lat. The highest concentrations are found on the slope in 400-500 m depth; in deeper water catches of hake were very poor. On the shelf exploratory fishing showed recently that hake is most abundant in the Golfo San Jorge. In the area between the Argentine coast and the Falkland Islands there are few but very big hake.

South of 45°N, hake is gradually replaced by *Micromesistius australis* which becomes the most important species on the slope. This species does normally not exceed ca 45 cm in total length.

Long tailed hake (*Macruronus magellanicus*)

This is the most important demersal species on the Falkland and Tierra del Fuego Shelf.

Croaker (*Micropagon opercularis*)

This species is most intensively exploited on the shallow parts of the Southern Patagonian Shelf.

5.4.2 Area review

Brazil

- 5°N to 2°S

The area off the mouth of the Amazon River deserves further explorations. Off northern Brasil the fishery is little developed except for crustaceans and not much is known about the potentials of the lightly exploited stocks. According to Beatty (Borgstrom and Heighway 1961) major resources seem to be flying fish (*Cephacanthus volitans*), tunas (*Parathunnus obesus* and *Neothunnus albacora*) and sharks. We should also expect smaller pelagic fish in the fertile region of the mouth of the Amazon. Bottom fish should be abundant in those areas where sedimentation of silt is not too heavy but organic detritus is still abundant. The shrimp potentials are discussed in the relevant chapter. No figures for fish potentials have been published. A total sustainable yield of 500,000 tons, perhaps split equally between demersal and pelagic species, might be expected if we assume 1.5 tons/km^2, in the fertile area off the Amazon (250,000 km^2) and much less, say 0.6 tons/km^2 in the remaining area off the northern Brasilian coast (200,000 km^2). These figures might be under-estimates. A study of the food transfer in a tropical shelf area with high primary production is badly needed.

- 2°S to 13°S

Off San Luis to Bahia, the shelf gets narrower and the productivity is low. The inshore banks are considered as being heavily over-fished and the offshore banks are increasingly exploited. Tuna off Recife are taken both by Brazilian and foreign (mainly Japanese) vessels. There may be some more potential in some offshore pelagic stocks, but no large scale expansion is expected. Excluding oceanic tuna fishing the potential of the stocks along the shelf will presumably be not more than 100,000 tons. Again, lacking better information, it will be assumed that half is pelagic and half demersal.

- 13°S to 23°S

Between Bahia and Rio de Janeiro, a large bank (Mar Nôvo) of about 70,000 km^2 seems very fertile (mixing at the Brasil Current with coastal waters) and has a good stock of demersal and pelagic fish. The stocks are increasingly exploited. A total potential of 200,000 tons - around 3 tons/km^2 - might be expected. As this is only a very vague guess, further exploration seems worthwhile.

- 23°S to 29°S

The fishery off Santos and Florianopolis is mainly on sardines (see above). The potentials of other pelagic species and of demersal fish are unknown. It appears that there are unexploited stocks of Anchoa (Pomotomus saltatrix) off Florianopolis. In spite of the existence of good shore facilities and marketing conditions, no large scale fishery developed except the fishing for sardines and shrimp.

There are some data on trawling by pair-trawlers (pareja) which gave average abundance estimates for demersal fish of 0.6 tons/km^2 while ordinary bottom trawlers got only 0.07-0.18 tons/km^2. If one takes the figures of pareja and allows arbitrarily for 33% escapement, then we arrive at figures of 0.8 tons/km^2 for the density of the present standing stock and a total biomass of 240,000 tons of bottom fish for the area between 23° and 29°S. Presumably in these warm waters, the rate of turn-over of standing stock and the natural mortality are high, perhaps as high as 0.8; this gives an estimate of demersal potential of 0.5 x 0.8 x biomass, or 96,000 tons, or 100,000 tons in round figures.

The main pelagic fishery is for sardines for which a rough estimate of potential of 100,000 tons has been obtained above. Probably, other pelagic fish could supply half as much again, giving a total pelagic potential of 150,000 tons.

- 30°S to 33°S

Brasilian trawlers prefer to move further south into the area of Rio Grande. For the area 29°-33°S, Richardson (1963) estimated catches of 3.4 tons/km^2, which should be corrected for escapement (33%) as 5.1 tons/km^2. This gives a total biomass of demersal fish in the region of a little under 400,000 tons. The area is rather heavily fished and the catches - recently around 75,000 tons - might be approaching the level of the potential yield. The apparent level of F implied by these figures, 0.2, is still, however, moderately low and some increase in demersal catch should almost certainly be possible, i.e. say to 100-150,000 tons.

- 33°S to 34°S

For the area from Rio Grande to 34°S (about 50,000 km^2 of shelf) we have two figures of abundance; U. Schmidt (personal communication) found 10.3 tons/km^2; while Richardson's figure (corrected for escapement which seems to be much higher for ordinary trawlers than for parejas - possibly ~50%) is about 7 tons/km^2. The standing stock might, therefore, be about 300-500,000 tons, the maximum sustainable yield of the already exploited stocks would then be again of the order of 150-250,000 tons of demersal fish.

In these two areas (south of 29°S), pelagic fish - anchovy, mackerel, etc. - are common, but no estimate of either potential or biomass is available. The potential may not be very different from the demersal potential, i.e. 300,000 tons.

The above estimates and guesses for the potential off Brasil have been summarized in Table M2 below. As in all these studies not too much attention should be given to the precise figures; for convenience of tabulation, comparison, and summarization, a single figure is given for each resource, but the true value may lie within quite a wide range on either side - differing by perhaps a factor of two for some of the resources given here.

Table M2 - Summary of estimated annual potential catches off Brazil ('000 tons)

Area	Demersal	Pelagic
5°N - 2°S	250	250
2°S - 13°S	50	50
13°S - 23°S	100	100
23°S - 29°S	100	200
29°S - 33°S	125	300
33°S - 34°S	200	
TOTAL	825	1,000

Uruguay-Argentina

The biomass of demersal fish in this area can be estimated from the data of the trawl surveys made by R.V. WALTHER HERWIG in May-August 1966 (Schmidt, personal communication). These summary data are set out in Table M3 (including data from north of 35°N). In this, the biomass has been estimated on the basis that in one hour trawling the net covered an area of 155,000 km² and caught 75% of the demersal fish in that area.

The shelf area of the open sea from 35°S (Rocha) to 40°S includes the rich fishing grounds of Mar del Plata and Bahia Blanca. Richardson's figures for Cabo San Antonio area show an abundance of 14 tons/km² (corrected for 50% escapement). He points to stretches with very high abundance of merluza where corrected figures up to 60 tons/km² might be obtained. Schmidt's average (Table M3) for the total shelf to 35°-41°S is 20 tons /km² (corrected for 25% escapement from the large trawl) in winter.

The main species is hake, of which Russian exploratory fishing caught up to 20 tons/hour (Zakharov 1968). The distribution of hake is also given by Biester (1967); the catches in the main area - 35°-40°S - are very similar to those of Schmidt. The area has been exploited by local vessels for a long time. Catches have steadily increased, up to 100-150,000 tons in the early 1960s, with a jump to 650,000 tons in 1967, when there was intense fishing by USSR. In comparison with this recent catch, and with the estimated biomass, the catches at the time of the WALTHER HERWIG survey were small; the potential yield may, therefore, be estimated on the basis of the 1966 stock being unexploited, i.e. as 0.5 x biomass x natural mortality.

The natural mortality of Patagonian hake is not known. The observations of Angelescu et al. (1958), and also Mikheyev (1967), suggest that it is high. Assuming a value of 0.6 and that the same value can be used for all demersal fish, the corresponding estimate of potential between 35°and 41°S is:

0.5 x 3.96 x 0.6 = 1.2 million tons, approximately.

This would tend to be an under-estimate to the extent that the stocks are already being exploited; on the other hand, Richardson's figures of density are rather low. Therefore, 1.2 million tons is probably not an unreasonable estimate, though the true value may differ quite largely to one side or the other.

Further south, the stocks are virtually unexploited. The major species is poutassou rather than hake. For it also, the natural mortality is unknown though the age composition data of Shubnikov et al. (1969) suggest an annual survival between 5 and 8 years old of ca 70%, or a natural mortality coefficient of 0.4. If this value can be applied to all the demersal stocks south of 41°S, which were at the time of the surveys unexploited, then the potential may be estimated as 0.4 x 0.5 x biomass. These estimates are given in Table M3. It is also assumed that the same factor can be applied to the demersal fish on the slope.

Table M3 gives an estimated total potential of nearly 3 million tons of demersal fish on the shelf south of 35°S. Possibly about half of this would be hake, which is the dominant species in the north, and the rest a mixture, with poutassou being probably the most important.

Table M3 - Biomass and estimated potential annual yields of demersal fish on Argentinean Shelf, from data of R.V. WALTER HERWIG

(a) On the shelf, 25-200 m

Lat. S or N	Width of shelf (km)	Shelf area ('000 km^2)	Average catch/hour (tons)*	Biomass ('000 tons)	Potential ('000 tons)
35 - 41	300	200	2.3	3,960	1,200
41 - 45	400	175	0.5	750	150
45 - 51	500	330	0.8	2,270	450
51— 54	700	230	1.6	3,170	650
54 - 55	300	35	0.2	60	10
TOTAL		970		10,130	2,460

(b) On the slope, 200-1,000 m

Lat.	Width of shelf (km)	Shelf area ('000 km^2)	Average catch/hour (tons)*	Biomass ('000 tons)	Potential ('000 tons)
35 - 41	20	13	4.7	525	100
41 - 45	50	20	0.6	100	20
45 - 50	100	55	1.0	475	100
50 - 54	100	35	1.1	330	60
54 - 56	30	7	0.4	25	5
TOTAL		130		1,455	285

Note - * Catch in one hour assumed equal to 75% of biomass in an area of 155,000 m^2

The pelagic resources can be estimated even less precisely with the exception of the anchovy stocks, for which an estimate of 0.5-1.0 million tons has been obtained.

Anchovy is the main food of the small hake (Zakharov 1968), the other major item being zooplankton (euphausids, etc.); larger hake feed to an increasing amount on small hake (over 50% for hake over 60 cm and also on squid). No other pelagic fish occurred in Zakharov's samples in substantial quantities. The egg surveys of de Chiechomski and Boschi (1968), directed at anchovy spawning areas, found eggs of other pelagic species (Brevoortia sp., Scomber japonicus, etc.) though not in great quantity. This information suggests that anchovy is the major pelagic resource, particularly in the northern part of the area. A rough guess of the potential of herring has been obtained above as 1-1.5 million tons. Allowing for other species, a very rough estimate for the potential of pelagic fish south of 32°S is 2.5 million tons.

5.5 Indications for unexploited stocks

Myctophids were found in large abundance over the slope in the area 32°-36°S. A single haul of a pelagic trawl of WALTHER HERWIG yielded 12 tons.

Squid (Illex sp.) has a similar distribution to hake, which feeds intensively on squid. The major concentrations of squid do not seem to reach as far to the south as hake does. Highest echo abundance and catches of squid (7.2 tons in one haul of pelagic trawl) were found off Rio de la Plata and Mar del Plata both on the shelf and the slope.

Too little is known about myctophids and squid to put any figures down about their potential yields, but they likely reach at least some hundreds of thousands of tons.

5.6 Summary of estimates for potential annual catches

The above estimates can be summarised as follows ('000 tons):

(a) Demersal

Brasil	various		825
Argentina-Uruguay	hake	1,500	3,000
	poutassou	1,000	
	various	500	

(b) Pelagic

Brasil	various		
Argentina-Uruguay	anchovy	750	2,500
	herring	1,250	
	various	500	

(c) Crustaceans (see separate chapter)	111
(d) Squid	(500)+
(d) Myctophids	(500)+

6. COMPARISON OF ESTIMATES OF THE MAXIMUM SUSTAINABLE YIELD WITH ECOLOGICAL POTENTIAL AND PRESENT FISHERIES

The region can be divided into three areas:

6.1 Equatorial Regional (Mouth of Amazon)

Rich in nutrients, high primary production, virtually unfished, except for shrimp and some tuna. Ecosystem presumably very complex and relatively inefficient in terms of production of fish on high trophic level. Potentials of pelagic fish might be considerable; much exploratory work is required.

6.2 Coast of central Brasil

Productivity relatively low except for the southern area where Brasil Current and Falkland Current meet at the edge of the shelf. Demersal stocks seem rather limited, although offshore banks carry some little exploited population. Larger expansion might be possible in fishing sardines, tuna, myctophids at the edge of the shelf. Further echo surveys are needed.

6.3 Shelf area of the Falkland Current - RioGrande to Tierra del Fuego and Falkland Islands

Primary production in this area is high, decreasing from south to north. Abundance of zooplankton and benthos is high and varied stock of food organisms is regarded as of the same order as in the North Sea, but the stock of plankton does not decrease in winter to the same extent as in the North Sea and water temperature remains higher in most of the region. Estimates of maximum sustainable yield of demersal fish are based on a rather limited fishing confined to some coastal areas only and for the southern part on the exploratory cruise of WALTHER HERWIG in winter 1966.

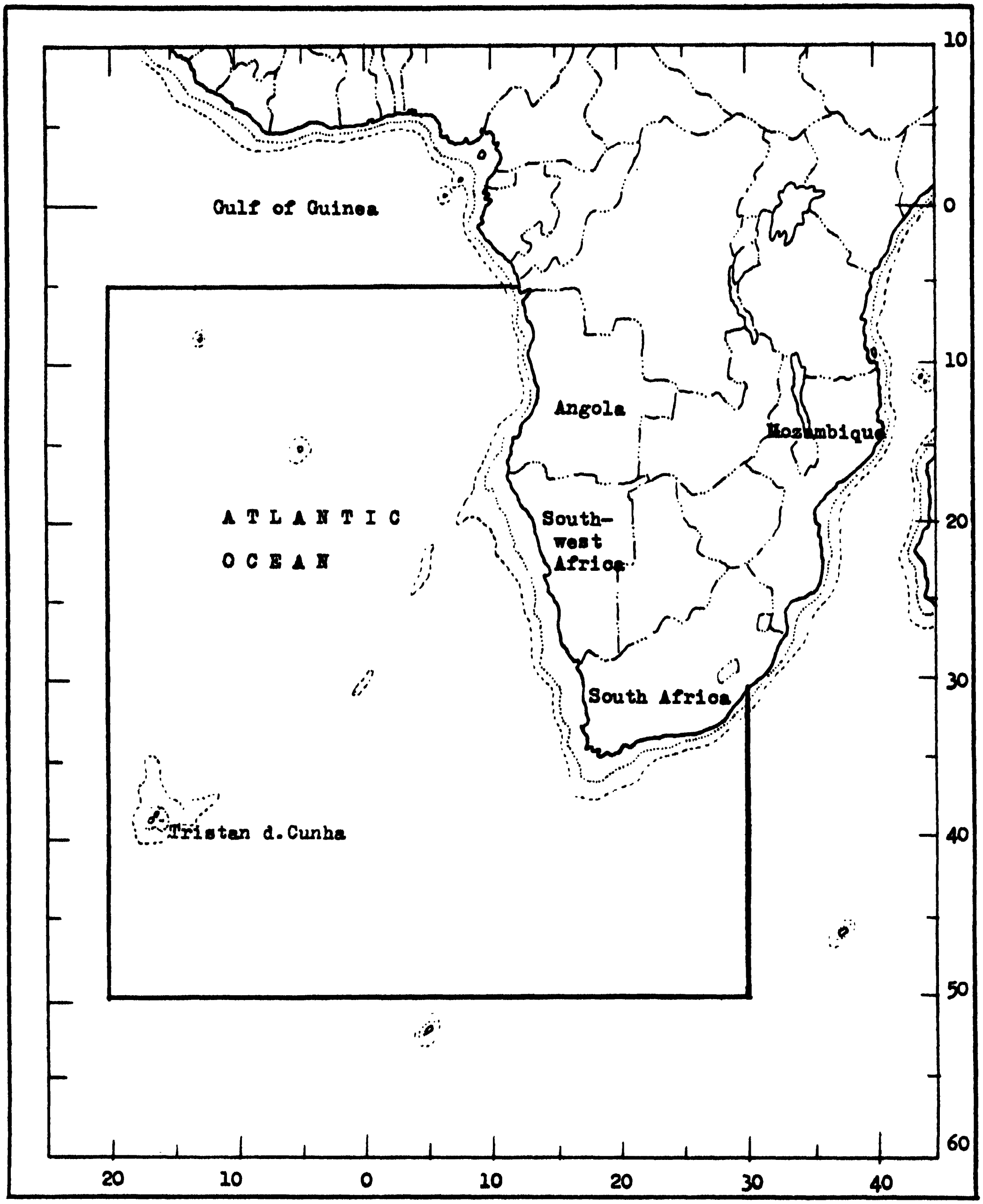
The estimated potential yields of demersal fish (2.6 tons/km^2) are higher than present demersal catches in the North Sea (1.6 tons/km^2) and this might be related to the longer season of high production on the Patagonian Shelf.

There is surprisingly low abundance of demersal fish of commercial size on Burdwood Bank in spite of high abundance of benthos.

Estimates of pelagic resources are extremely uncertain compared to other more fully exploited fishing areas of the world.

7. FUTURE STUDIES

All the estimates of potential presented here are extremely rough, and subject to a wide range of possible error. A correspondingly wide range of research is required to improve them. Lines of study, which are likely to be particularly useful, include: an assessment of the hake stocks on the Argentinean Shelf, especially taking into account the heavy fishing by long-range vessels after 1966; further surveys of demersal fish, by trawl or otherwise; and surveys, e.g. by acoustic methods of the pelagic stocks, especially in the south. Certain aspects of the statistics, especially data on fishing effort, and on location of catches of long-range vessels, should be improved.



N - SOUTHEAST ATLANTIC

Depth contours at 200 and 2,000 m

1. TOPOGRAPHY

As defined here, the area extends from 6°S (the mouth of the Congo River) round the Cape of Good Hope to 30°E (a little south-west of Durban) excluding the Antarctic waters south of 50°S. The latter boundary is rather to the east of the line usually taken as the division between the Indian Ocean and the Atlantic (20°E long., through Cape Agulhas), but has been chosen to avoid dividing the important fishing grounds of the Agulhas Bank. The fish fauna between 20° and 30°E are mainly cold-water species and more like that of the South Atlantic than that of the Indian Ocean.

In the north of Angola, the continental shelf is moderately wide (ca 50 km), but becomes very narrow in southern Angola (ca 20 km). Off South-West Africa, and the northern part of South Africa, it widens again and unlike many other areas there are particularly wide stretches of moderately deep water (200-1,000 m). Thus, at 30°S, the 200 m contour is about 70 km from the coast, but the 700 m contour is over 200 km offshore. South-east of Cape Town, the shelf widens to form the only important offshore bank in the area - the Agulhas Bank. Further east, the shelf narrows again to around 40 km.

There are few islands in the area; the small oceanic islands of Ascension, St. Helena and Tristan de Cunha lie in the area. The Vema seamount, north-west of Cape Town does not reach the surface, but is sufficiently shallow to have supported an important rock lobster fishery.

2. HYDROGRAPHY

The major current in the area is the Benguela Current flowing northwards off the west coast of Africa between 35° and 15°S (Hart and Currie 1960, Stander 1964). Towards the north of the area, the Benguela Current swings westward to form the South Equatorial Current. The other current near the coast is the warm Agulhas Current flowing south and westward along the south-east coast of Africa (Darbyshire 1964). To the south, the main current is the West Wind Drift.

The Benguela Current causes upwelling along the west coast of southern Africa, the extent of which varies seasonally. Between Cape Point and the Kunene River, a certain amount of upwelling occurs throughout the year. North of the Orange River a peak in upwelling occurs in September and the corresponding minimum is usually in March. South of the Orange River, peak upwelling is found in February while a minimum occurs in August. This brings cold water (12 - 16°C) close inshore, extending as far north as southern Angola in the winter. In contrast, the warm Agulhas current causes the coastal waters east of Cape Town to rise to 20° in the summer and 14 - 18° in the winter.

3. PRIMARY PRODUCTION

The most important feature in the area is the high primary production in the upwelling areas of the Benguela Current. The Galathea Expedition (Nielsen and Jensen 1957) found some of the highest rates of carbon fixation in the area (1.5 gC/m²/day, equal to an annual rate, if maintained for the whole year, of over 500 gC/m²/year). Cushing (1969), in a general review, has estimated the total carbon fixation in the upwelling areas of the world, taking into account the rate of production, the duration of the upwelling season, and the area of upwelling. He estimated the fixation in the Benguela upwelling (taking into account the 45% correction to the original estimates (Nielsen 1964, Goldman 1968)), as around 375 x 10^6 tons C/year. This is a very high figure compared with those for other upwelling areas, bigger than his estimate for the Peru/Chile upwelling, and an order of magnitude greater than that for California.

Outside the upwelling areas estimates of primary production are scarce but appear to be at the moderate to low levels typical of sub-tropical waters (around 50 gC/m²/year).

4. ZOOPLANKTON

Most observations have been concentrated in the main areas of interest to the coastal pelagic fisheries, off St. Helena Bay (de Jager 1954) and off Walvis Bay (Unterüberbacher 1964). Some other observations have come from the Meteor Expedition (Hentschel 1933). The former were mainly taken with tow-nets, and are, therefore, not immediately suitable for quantitative estimates of production. Off Walvis Bay, they show a clear bank of high standing crop (30 - 50 cc per haul, excluding fish larvae, salps and big Medusea and Ctenophores) about 50 km offshore, presumably corresponding to the centre of the upwelling. The main constituents were copepods. High values of average annual standing crop were also found in St. Helena Bay, but the abundance decreased rapidly away from the coast.

Using the Meteor data and comparisons with other areas, Cushing (1969) estimated the density of standing stock and total production in the upwelling areas, in terms of carbon content, as 4 - 8 gC/m², and 10 - 15 x 10^6 tons C per year respectively.

5. THE FISH AND FI

5.1 Statistics

Good statistics are available of the landings by the coastal countries (Angola, South-West Africa and South Africa), but effort data are scarce; for the fisheries on pelagic fish available or readily obtained statistics, e.g. on number of vessels, etc., are in any case probably rather poor measures of the true fishing effort, in the biological sense. Specific data on location of capture are also scarce, but at least until very recently long voyages were not made, and the place of capture corresponds closely to the point of landing.

For the long range vessels from Europe and Asia now operating in the area, the statistics are not so good. Total catch is available, but the breakdown by area and species is not always available, nor are effort data. However, the statistics are being improved and the ACMRR/ICES working group obtained reasonable estimates of total catch of the major species by major areas and of catch per unit effort.

5.2 The fisheries

Until recently (with the exception of one exploratory voyage for mackerel by the US schooner ALICE in 1889) fishing in the area has been entirely by the coastal states. Three major fisheries can be distinguished; that for shoaling pelagic fish (sardine, maasbanker (*Trachurus*), etc.) carried out from South Africa, South-West Africa and Angola; the trawl fishery (mainly for hake, *Merluccius*) from South Africa; and the rock-lobster fishery from South Africa and South-West Africa. In addition there are a number of minor fisheries, including the fishery for snoek (*Thyrsites atun*), from South and South-West Africa; small South African fisheries for shrimps, and for abalones and the shellfish, and tuna fishing from Angola. Of these the crustacean, mollusc and tuna fisheries are discussed separately in other reports of this series dealing with each of these three resources on a world basis.

In the late 1950s Japanese tuna vessels started fishing in the Atlantic and a part of their catches came from the present areas. In 1962 trawlers from Spain (fishing mainly for hake), and Japan started fishing in the area. Since then, a number of other countries have sent long distance freezer trawlers to the area - including USSR, Germany, Greece, Israel, Belgium and Korea. The main interest of these vessels has been in hake, though the Japanese also fish for various sea breams, etc., and for cephalopods, and the Soviets for pelagic fish. The hake catches of these long range vessels in 1968 accounted for at least 500,000 tons, compared with 120,000 tons by local vessels.

The hake fishery from South Africa was until recently mainly limited to the Cape Grounds (south of 31°S, and west of 20°E), but lately the activities of both the South African and long range trawlers have spread north, particularly off the Orange River and Luderitz. Fishing has also become deeper, down to 1,000 m. The catches of the coastal fisheries for pelagic fish have been controlled by quota regulations and by limitation on the number of processing plants and catching vessels (Gertenbach 1962); the quotas have been increased at intervals over the last ten years. In addition, converted whale factory ships have recently been working off South-West Africa whose catches were, until 1969, not included in the local quota.

5.3 Stock assessment

Hake

The state of the hake stocks has been reviewed by a joint ACMRR/ICES working party (ACMRR(FAO) 1968) and by Jones and van Eck (1967). Cushing (1968) has made quantitative estimates of the standing stock using echo sounder data.

The southern stock on the Cape Grounds (for which the best series of catch and effort data is available) appears to be fully exploited, with the greatest yield, with the present mesh size, of around 110,000 tons, taken with the effort at around the 1967 level. This figure includes an allowance for the appreciable quantity of hake that is at present discarded at sea, or used for meal. The landings, especially the part used for human consumption, would certainly be increased if a larger cod-end mesh size were used by the trawlers. The catches might also be increased, perhaps up to 125,000 tons.

The state of the stocks on the northern grounds is not quite so clear. The catch per unit effort of Spanish trawlers (mainly on these grounds) was, in 1967, 13.4 kg/ton-day, compared with 33.1 kg/ton-day in 1965. The length and age composition on the Luderitz Grounds in 1966 and 1967 were very similar to that on the Cape Grounds. The echo survey, from Walvis Bay to Cape Town, showed that the proportion of the total hake stock which was on the Cape Grounds was $\frac{.922 \times .257}{.71} = .333$, while rather less than one-third of the total catch comes from these grounds. Using the echo survey data, the fishing mortality coefficient, F, for all grounds combined was estimated as 0.43. Taken together, these data suggest that the northern stocks are as heavily fished as those in the Cape Grounds. If the Cape Grounds account for one-third of the total potential, then this total might be estimated as 3 x 125 = 375,000 tons. This at first sight appears low compared with annual landings in 1966 and 1967 of the order of 400,000 tons, though these catches will have included an element from the reduction of an initital high standing stock (fish up to 10 years old were present), which cannot be sustained for very long. It is estimated (ACMRR(FAO) 1968) using the echo survey data, that a stock of 2.9 million tons in 1965 declined to 1.2 million tons in 1967. This decline seems large in relation to the total catch (or more specifically the total catch less natural increase - growth and recruitment less natural mortality), and would suggest that the stock may have been over-estimated. There is, therefore, not necessarily any inconsistency between the catch records and a potential sustained catch of only 375,000 tons, though if this figure is in error, it may be too low, but is unlikely to be much too high. Allowing for some under-estimation, and rounding off a reasonable round figure for the total hake potential between Walvis Bay and Cape Town might be 500,000 tons - 360,000 tons off South-West Africa and 140,000 tons off South Africa.

Detailed assessments have not been made of the other demersal stocks, but it was estimated that 71% of the fish sampled by the echo survey were hake. If this proportion can also be applied to the potential, then the potential of other fish (kingclip, bream, etc.) is $\frac{.29}{.71} \times 500,000 = 200,000$ tons.

Pilchard (Sardinops ocellata)

The most detailed assessment of a pelagic stock is that of the pilchard off Walvis Bay by Newman (in press). On the basis of extensive tagging results and other data he concluded that the average fishing mortality in 1963/6 was 0.155. The corresponding yield per recruit was 33 g; and the maximum yield per recruit appears from his graph to be rather less than 90 g. In 1963/6 the average annual catch was 600-650,000 tons; if the recruitment remains constant following increased fishing then the yield might be increased to 0.65 x 90/33, or around 2 million tons.

However, Newman draws attention to the decline of the Californian sardine and its replacement by anchovy, at a fishing mortality of around 0.4 (Murphy 1966). A similar change has occurred in South Africa (Stander and le Roux 1968) and elsewhere.

Cushing (MS) in a general review of the relation of recruitment to adult stock and to the rate of exploitation also concludes that in several clupeoid stocks recruitment has declined at values of fishing mortality above 0.4. The greatest yield would then be taken at a fishing mortality of about 0.4, when the yield per recruit is only 53 g. If the recruitment is then still the same on the average as in 1963/6, then the yield would be 0.65 x 53/33, or a little over 1 million tons; this is probably a more realistic estimate of the potential yield than the figure of 2 million tons, based on the assumption of constant recruitment.

If fishing on pilchards is intensified beyond a certain level it may well be that the catches will decrease sharply. Under these conditions the pilchard may be replaced by anchovy, perhaps with no great change in overall productivity. There may be some differences, depending on the stock-recruitment relations for the different species, and their possible interaction. Lacking better information a potential of 1 million tons will be assumed; the species composition may vary with different patterns of fishing, and also with environmental conditions.

No such explicit assessment has been made for the stock of pilchards off St. Helena Bay. Several reviews have been made of catch statistics and other information (Davies 1957, 1957 a, 1958; du Plessis 1959; Stander and le Roux 1968). From these, it appears that some of the fluctuations in total catch can be readily explained in terms of variations in year-class strength. Between 1950 and 1956 and especially in 1954/5 small fish (less than 20 cm) were not common in the catches; recruitment during the later part of this period appears to have been low, so that by 1955/6 the stock consisted of a rather small number of old fish, and the total catch was low. In 1957 signs of the recruitment of a new strong year-class were visible (fish between 15 and 18 cm) and catches increased sharply in 1958 and 1959 (1953/7 average 100,000 tons, 1958 195,000 tons, 1959 260,000 tons). Good year-classes, combined with increased fishing, gave high catches up till 1963 (peak 410,000 tons in 1962). Since then catches have declined, apparently through poor recruitment. A feature of the post-1957 catches has been the low proportion of large fish (over 23 cm). It is tempting to ascribe this to the effect of increased fishing mortality, though, particularly if large and small fish school separately, changes in the pattern of fishing may also have had some effect. Good measures of true fishing effort (proportional to the mortality caused) are not available, but the total hold capacity of the fleet increased by nearly 50% between 1960 and 1965 (Stander and le Roux), and this probably under-estimates the true increase in fishing capacity. The great decrease in big (and old) fish, and the failure of the catches to be maintained after 1963, despite the large fleet, suggests that the stocks are heavily fished, with a potential (for recent recruitment levels) of 250-400,000 tons, depending on the recruitment.

While fishing for pilchard is concentrated on two rather small areas (off Walvis Bay and St. Helena Bay), plus a very small fishing off Natal and a fishery off Luderitz, which started in 1964 (Newman, in press) and produced 90,000 tons in 1966, the fish occur all along the coast from Angola to Natal. Nothing definite appears to be known about stock separation, but three possibilities exist concerning the fish south of Angola.

(i) there is one stock, exploited in two areas;

(ii) there are two stocks, both heavily exploited;

(iii) there are more than two stocks, only two are heavily exploited, and there are unexploited stocks in the area between Walvis Bay and Lamberts Bay.

Recent analysis of tagging data by Newman (in press) show that some 40% of the fish landed at Luderitz consist of migrants from Walvis Bay, but migration between Walvis Bay and the Cape is small. The second possibility (two independent, and heavily exploited, stocks) seems the most likely.

Regarding the total potential of the region, there is a most important difference between (i) or (ii), and (iii). If unexploited stocks exist the total potential may be much in excess of the sum of the resources in the two exploited areas. Pilchard certainly exist off Luderitz and the Orange River, and the position of the main centres of the pelagic fishery may be determined as much by the availability of suitable ports, as by the position of the main concentrations of fish. However, the South African based factory ships have been working close to Walvis Bay, rather than further south, and this suggests that the fish between Walvis Bay and Cape Town are not so abundant as off Walvis Bay.

The critical question, however, is not so much whether the fish are present in these intermediate areas, as whether they are separate and can be fished independently of the stock to the north and south. There appears to be little information available on this. Some tagged fish from South-West Africa have occurred in South Africa, but there is no evidence of large scale movement (Stander and le Roux 1968). This and the fact that the two main fishing areas seem also to be the major spawning grounds suggest that there is not a major independent stock between Walvis Bay and Lamberts Bay.

Pilchard and anchovy

Following the experience in California (Murphy 1966) there is anxiety concerning the possibility of fishing causing the replacement of pilchard by anchovy (*Engraulis capensis*). Stander and le Roux (1968) show that there has indeed been an increase in anchovy off South Africa. The relevant information from their paper is given in Table N1.

The density of adults has been estimated as the product of the catch per unit effort (landings per tons of hold capacity) times the percentage of adults. This shows fair agreement with the number of eggs caught per plankton net haul (increase to a peak in 1960/1, and decline since then) suggesting that both are giving a reasonable measure of the stock of adult pilchards.

The blanket net catches of young fish also agree in showing peak pilchard catches around 1961, but later catches have been much lower than might be expected from the eggs. At the same time, the number and percentage of young anchovies has increased; the total number of young fish shows no clear trend.

There is, therefore, an increase in anchovy, at the same time that there appears to have been a decrease in pilchard. However, the main increase in anchovy was between 1956 and 1962; the first part was before the period of high pilchard catches and the second a time when the abundance of adult pilchards and pilchard eggs was unusually high. It is doubtful, therefore, whether the increase in anchovy can be ascribed to a reduction in pilchard stocks by fishing, though the increased anchovy stock might be a cause of the reduced survival of pilchards from eggs to young fish (as measured by the ratio of number of young fish/haul to the catch per unit effort of adult pilchard) which is apparent since 1962.

Table N1 - Pilchard and anchovy off South Africa

	Commercial fishery				Plankton	Blanket net samples			
	Total catch ('000 tons)		Adult	Pilchard		Numbers per haul			
	Pilchard	Anchovy	(a)	(b)	(c)	Pilchard	Anchovy	Total	% Anchovy
1950	86		93	9.8					
1	99		98	11.8					
2	169		88	19.5					
3	136		97	15.2					
4	88		99	11.0					
5	121		100	13.6	177				
6	76		94	7.5	88	104	7	121	6
7	107		84	7.9	14	218	18	236	8
8	195		47	10.4	(1)	54	27	81	33
9	260		36	11.1	39	40	21	61	34
1960	318		49	20.7	108	34	142	176	81
1	402		84	40.0	1,399	160	100	260	38
2	411		69	31.7	466	428	632	1,060	60
3	401	23	47	19.0	242	7	64	71	90
4	257	95	47	11.7	485	5	96.5	101	96
5	207	209	47	8.9	66	9	72.8	82	89
6	118	157							
7	81	276							

Notes - (a) Percentage of adult pilchards in catches

(b) Catch per unit effort of adult pilchards

(c) Number of pilchard eggs caught per plankton net haul

5.4 Other evidence of potential

Eggs and young fish

Routine surveys for pilchard eggs and larvae have been made off St. Helena Bay (Davies 1954) during which other species were recorded. The commonest pelagic species, other than pilchard, was maasbanker. Anchovy and round herring (*Etrumeus micropus*) also occurred (though the data were collected before the increase in anchovy noted above), as did larvae of lantern fishes (*Myctophum* and *Maurolicus* spp.). Among demersal species post larvae and juveniles of hake were frequently obtained, and other demersal species already commercially exploited such as John Dory (*Zeus faber*), Jacopever (*Sebastichthys capensis*) etc. occurred in smaller numbers.

During the surveys other observations on fish were made. In addition to the species noted above, snoek (*Thyrsites atun*) were caught on hand-lines, and saury (*Scombresox saurus*) were frequently seen when attracted to the ship's side by lights, especially at the westerly stations in the warmer water. Squid (*Loligo reynaudi*) were also very common.

In the inshore area, a number of other species (silverside, *Atherina breviceps*, whitebait, *hristi aestuarius*, mullet, *Lisa ramada*) were found, post-larvae and juveniles of Cape Rockli (*Gaidropsarus capensis*) being particularly abundant. Young fish surveys were carried out off South Africa, using a blanket net (Davies 1957 a). In the 1955/6 surveys a total of 3,672 pilchard, 23,124 maasbanker, 343 anchovy, and 3,996 round herring were caught.

Food of larger animals

The food of several of the major predators on fish round South Africa has been studied in detail in several papers. Rand (1959) has studied the fur seal. From 245 seals killed at sea, the relative percentage contributions of the major food items, in terms of volume, were as follows:

Maasbanker	44.2	*Loligo* sp.	6.5
Pilchard	14.3	*Octopus* sp.	15.8
Sebastichthys	2.8	Rock lobsters	2.1
Other fish	13.6	Others	0.6

The total consumption of fish by fur seals was estimated as 11,500 tons. The food consumption by birds off South Africa has been studied by Davies, and in more detail by Rand (1959 a, 1960, 1960 b). Similar studies have been made off South-West Africa (Matthews 1961). The results in terms of the percentage composition by weight or volume are given in Table N2 below:

Table N2 - Percentage food consumption by southern African birds (1955/6)

	South Africa			South-West Africa		
	Gannet	Penguin	Cape Cormorants	Gannet	Penguin	Cormorants
Pilchard	51	27	11	87	94	87
Maasbanker	20	15	22	3	<1	9
Anchovy	12	21	14	-	-	<0.5
Mackerel	5	3	1	-	-	-
Sand-eels	-	4	24	-	-	-
Other fish	6	10	10	4	1	1
Unidentified fish and fish remains	4	5	12	6	5	2
Crustaceans	-	10	6	-	-	-
Cephalopods	2	4	-	-	1	-

The food of the fish caught in the trawl fishery, particularly the hake, has been studied by Davies (1949). The food of hake varied with the size; the smaller ones feeding on euphausids and myctophids, with small quantities of other animals - cephalopods, mysids, etc., while the larger hake fed largely on small hake, and some maasbanker and rat-tail, Coelorynchus fasciatus. The latter species, itself an important element in the trawl catches, mainly feeds on bottom crustaceans (Pagurus spp.) etc. The food of the other fish (Dory, Zeus faber, Jacopever, Helicolenus maculatus, Kingclip, Genypterus capensis), consisted of the same organisms in different proportions.

6. DISCUSSION AND SUMMARY

The assessments obtained above for the potential of some of the fish stocks are set out in Table N3, in which the estimates have been separated for three major areas - off Angola, South-West Africa and South Africa. These estimates are the (rather few) figures in Table N3 which are not in brackets.

For demersal fish the total potential between Walvis Bay and the Cape (500,000 tons hake, and 200,000 tons other fish) has been divided in accordance with the echo survey data to give 140,000 tons hake and 110,000 tons others between Walvis Bay and the Orange River, and 360,000 tons hake and 90,000 tons others south of the Orange River. These figures are given in Table N3. To these should be added the potential north of Walvis Bay and east of the Cape. About half of the shelf area off South-West Africa lies north of Walvis Bay and the hydrographic conditions seem similar. Therefore, it is reasonable to assume that the demersal potential in this area is the same as between Walvis Bay and Orange River. Dividing it between hake and other fish in accordance with some research vessel observations (ACMRR(FAO) 1968) gives a total of 80,000 tons hake, and 170,000 tons other fish.

The hake stocks off the south coast, including Agulhas Bank, are probably not independent of those on the Cape Grounds, and also the catches from the south-eastern grounds have probably to some extent been included in the statistics of total catch used in analysing the Cape stocks. Thus, the figure of 360,000 for the hake potential off the west coast of South Africa includes a contribution also from the south coast; the figure for the total potential is, therefore, not much higher than, say, 400,000 tons of hake. The potential of the other demersal stocks north-west of the Cape was estimated from the echo survey, so the potential to south-east should be added directly; the latter area is rather greater, but appears to be less productive; as a first approximation, the potential in the two areas might be taken as equal, i.e. 90,000 tons.

Off Angola there are no good data on demersal potential. Hake are virtually absent and typically rather warmer water species are caught. About 10,000 tons of various breams, croakers, etc. plus 25,000 tons of unsorted fishes (probably mainly demersal fish) are landed in Angola. Biologically the area appears to be not much less productive than further south; the upwelling region extends well into Angola at least seasonally, and intuitively one would expect the centre of fish production to be located downstream of the centre of primary production. Off northern Angola there are good stocks of sparids (especially Dentex angolensis) in 50-70 m which appear to be little exploited.

Expressed as potential per unit area within 1,000 m, the demersal potentials off South Africa and South-West Africa are very similar, ca 25 kg/ha. Taking a similar figure for Angola gives an estimate of 225,000 tons.

These various estimates obtained above are given in brackets in Table N3.

Among the pelagic stocks estimates of potential have been obtained for pilchard; there are 1 million tons of pilchard from the ground off Walvis Bay and 250-400,000 tons of pilchard off St. Helena Bay. To these figures should be added the potential of other pilchard stocks; catches off Angola, used almost entirely for fish meal, have reached over 100,000 tons (in 1964), but have tended to decline recently. In view of the world-wide tendency to increase production of fish meal wherever possible, this does not suggest a large under-exploited potential, though other factors, e.g. loss of factories (Reis 1968) may have inhibited any increase. A guess is that the potential might be 200,000 tons. Probably, but not certainly, there are no substantial unexploited pilchard stocks south of Walvis Bay; some small allowance for the possibility of such stocks can be made by taking the upper figures for the potential off South Africa.

The potential of the other pelagic stocks might be judged by comparison with the pilchard. Off Walvis Bay, the food consumption by birds strongly suggests (especially by comparison with the food of the bird off South Africa) that the pilchard is the only important coastal pelagic fish. Possibly the banker potential is 10% of the pilchard, and probably there is a potential of Sardinella aurita off the northern part of South-West Africa, perhaps of the order of tens of thousands of tons (indicated by x10 in Table N3).

Table N3 - Estimates of potential of the Southeast Atlantic

	Angola	South-West Africa	South Africa	Total	1967 catches
Length (km)	1,250	1,300	1,500	4,050	
Area: 0-200 m ('000 km^2)	50	85	150	280	
0-1,000 m	90	200	230	520	
POTENTIAL					
Demersal					
Hake	-	360 + (80)(a)	140 + (40)(a)	620	420
Others	(225)	110 + (170)(a)	90 + (90)(a)	460	120
TOTAL	(225)	720	360	1,080	540
Coastal pelagic					
Snoek	-	(20)	(20)	(40)	15
Pilchard	(150)	1,000	(150 - 300)	1,400	1,106
Anchovy	(100)	(x10)	(200 - 750)	650	300
Maasbanker	(400)	(200)	(150 - 400)	800	195
Mackerel	-	(x10)	(50 - 150)	150	140
Sardinella	(650)	(x10)	(x1)	700	-
Round herring	-	-	(x100)	300	-
Sand-eels	-	-	(x10)	50	-
TOTAL	(1,300)	(1,300)	(700 - 1,800)	3,900	1,740
POTENTIAL PER UNIT AREA OF SHELF (to 1,000 m) (kg/ha)					
Pelagic	(145)	115	(55)		
Demersal	(25)	36	16		
TOTAL	170	150	71		
OTHER SPECIES (not considered by areas)					
Saury	(x100)				
Pomfret	x10				
Squid	x100				
Myctophids	x100				

Notes - Figures in brackets denote estimates based on particularly inadequate data

(a) Bracketed figures denote estimates for grounds outside the area covered by echo surveys (see text)

(x1), (x10), (x100) denote quantities believed to be a few thousands, tens of thousands or hundred of thousands respectively

The feeding of birds and seals show that the other coastal pelagic fish are relatively more important off South Africa, though it would be difficult to use the data quantitatively. The young fish surveys, using blanket nets, are fundamentally more quantitative, but have been rather restricted in

Taking all the evidence together suggests that the potential of maasbanker is as high as that of pilchard (it was commoner in stomachs of hake and seals and in blanket nets, but birds ate fewer); anchovy may now be more productive (quite common in birds' stomachs even in 1955/6; now very much commoner in blanket net samples). Round herring may be rather less productive - of the order of a hundred thousand tons and mackerel less still - perhaps tens of thousands of tons. *Sardinella aurita* occurs but is rare. This would suggest potentials, for the conditions of 1955/60, as follows (in '000 tons):

pilchard	250 - 450
maasbanker	250 - 500
anchovy	100 - 300
mackerel	50 - 100
TOTAL	650 - 1,350

Since then there has been a change in the balance of species, as shown in both the catches in the commercial fishery and research data; assuming, as seems reasonable, that the pilchard is still about fully exploited, the potentials under 1967/8 conditions might be:

pilchard	100 - 150	
maasbanker	50 - 250	(commercial catches suggest a serious decline)
anchovy	300 - 1,000	(up to 10 times pilchard, see Table N1)
mackerel	50 - 200	
TOTAL	500 - 1,600	

The means of the two periods are shown in Table N3.

Comparing these figures with the actual catches (Appendix Table N1) suggests that the anchovy is still under-exploited. The lack of any obvious trend in the total pelagic catch, which since 1960 has varied between 350,000 and 550,000 tons, suggests that the potential may not be very much above this level, i.e. in the lower range of the tabulations above. The biggest discrepancy between potential and catches is for the maasbanker; the present estimates, based on feeding by other fish and birds suggest that it is only lightly exploited. However, the catches have decreased in the last ten years at a time when the decrease in the most favoured species (pilchard) might be expected to have resulted in increased effort in maasbanker.

Sand-eels (*Ammodytes capensis*) occurred quite commonly in the stomachs of cormorants. Experience in northern waters show that sand-eels form a resource which is frequently neglected by fishery interests, though when present the larvae may be dominant elements in the plankton. Larval sand-eels did not appear frequently in the plankton off South Africa, so probably the potential is not large (perhaps some tens of thousands of tons). In addition to these small pelagic fish, larger fish, e.g. snoek, are present. Being predators, their potential will not be so large, perhaps 40,000 tons, equally divided between South Africa and South-West Africa (there is migration of snoek between the two areas).

The potential off Angola is even less easy to estimate. Catches of maasbanker (*Trachurus*)are high, and showing some tendency to increase *Sardinella aurita* are common off Angola (Monteiro 1956, Postel 1960). Anchovy also occur, especially in the south. Cheno (1966) suggested that the Angolan catches of both pelagic and demersal fish could be greatly increased. It seems reasonable to suppose that the potential of Angolan waters is similar to that of the comparable coasts of South-West Africa and South Africa; though the width and area of shelf is less, the length is about the same, and thus is probably the more critical factor so far as the pelagic resources are concerned. These may, therefore, be estimated as being around 1.3 million tons; a suggested division between species is given in Table N3.

Other stocks

There are signs of other species, mostly oceanic, which though not exploited in the area, are fished elsewhere. Two notable examples are the saury (Scombresox saurus) and the squid (Loligo reynaudi). Both of these appear to have an oceanic distribution, or at least are not confined to waters moderately close to the coast, as are the species discussed above. Their yield, therefore, will depend on how far fishing could in practice extend. Probably the resources of both species are at least of the order of hundreds of thousands of tons. Myctophids, which are an important element of food for several species (Davies 1949), form another resource which is clearly large, though at present requiring some technological advances to make its large scale exploitation in offshore areas economically feasible. Newman (personal communication) reports that "Since the introduction of anchovy nets in the Western Cape occasional catches of lantern fish have been made, either pure or mixed with other species. Two myctophids are involved, Lampanyctus hectoris and Myctophum humboldti, but most of the landings have been of L. hectoris. Average weights ranged from 0.8 g to 3.1 g and caudal lengths from 4.4 to 7.3 cm. Catches have been made by pelagic boats at night, between Lamberts Bay and Cape Columbine in water ranging from 15 to 140 fm.

The oil yield from these fish is reported to be high, that is, in the vicinity of 30 galls per ton. Separate landing weights are not readily available, but individual catches from 8 to 25 tons have been reported. The total landings in each of the past two years have not exceeded three figures in South African waters."

Comparison with other areas

The total potential of the area including species such as squid and myctophids for which explicit estimates of potential have not been obtained, may be estimated as 5-6 million tons. This is quite high (e.g. Northwest Atlantic potential is 6 million tons, Northeast Atlantic 15 million tons) but is consistent with the high primary production in the area. The relation of upwelling to fish production is discussed in more detail by Cushing (1969).

Improvement of estimates: further studies

All the estimates presented here are subject to great variation, and all aspects discussed here should be made more precise. However, certain aspects seem to be particularly important in deriving better estimates. These include:

(a) Further studies along established lines, of the population dynamics of the major exploited stocks, especially pilchard and hake, for which extensive data are already available;

(b) Determination of the identity of separate stocks; especially for pilchard and of the relation of the pilchard occurring outside the main fishing areas to those of the fishery, e.g. by tagging at intervals along the whole South African/South-West African coast;

(c) Surveys, preferably combining echo surveys and fishing, of the stock and areas which appear to be particularly lightly exploited, i.e. anchovy off South Africa, and the pelagic stocks generally off Angola;

(d) Experimental fishing and other studies to determine the possibilities for fishing for squid and saury.

INTRODUCTION

The richness of the living resources of parts of the Antarctic seas were noticed by the earliest explorers. The problems of evaluating, and using, these resources are quite different from those in other areas. The climate and distance from markets or major ports make exploitation difficult, while some of the main elements in the ecosystem which support the main fisheries elsewhere - shoaling pelagic fish and large or medium demersal fish - are absent in the Antarctic. However, the large whales have supported a large industry, supplying some 10% of the world marine catch in the 1930s, and considerable attention is now being paid to Antarctic and sub-Antarctic resources, e.g. krill, now that the limits of the potential of other resources are being approached. Recent reviews of the general knowledge of Antarctic resources are available in Holdgate (1970) and, for Russian research, Marty (1969).

1. TOPOGRAPHY

1.1 The northern boundary of the Antarctic Ocean is conveniently given by the Antarctic Convergence, which, however, does not preclude free exchange of large water masses in deeper layers. Several authors describe the Great Southern Ocean reaching the tips of the African and American continents. In terms of surface waters and their fauna, the Antarctic Ocean is an entity in spite of the fact that it has an open and free connection with the three great oceans. The southern boundary is the Antarctic continent.

Even in summer parts of the area are inaccessible; south of the Convergence in winter, however, ice covers up to half the area that is ice-free in summer.

1.2 The major part of the continental shelf is narrow, depressed by ice to great depth. It is generally covered by ice during most of the year and cannot be fished by conventional methods. The islands and submarine ridges have no large areas of shallow water. There are shallow areas of some importance around Kerguelen Islands and South Georgia.

1.3 The oceanic area is mainly a deep ocean with depths of 4,000-5,000 m and covered with diatom ooze in the northern half, and blue clay in the south. The South Antilles Area rises from the deep sea floor and is of great importance to the circulation of the Southern Ocean and its ecosystem.

2. HYDROGRAPHY

2.1 The water masses of the Antarctic Ocean are of three major layers moving in different directions.

(a) Surface water moving generally eastward (West Wind Drift) but deflected by the Antarctic peninsula into a north-easterly direction, protruding far northward (Weddell Drift). Close to the continent there is a westward drift. The surface water is cold and of low salinity throughout the year.

(b) Underneath there is an influx of relatively warm (0.5-2°C) and highly saline water from the north. This "warm deep water" starts to climb up at the Antarctic Convergence and becomes the impressive Antarctic Circumpolar Water. It reaches the periphery of the continent. If the warm water does not upwell in open waters or areas of very thin ice cover, it cools down on its travel to the south until it freezes.

(c) The cold bottom water which moves northward.

At the Antarctic Convergence, the cold surface water sinks below warmer mixed water. South and north of the Antarctic Convergence the general direction of the surface currents is eastwards with velocities averaging about 1/3 knots (0.15 m/sec).

2.2 Surface temperature close south to the Antarctic Convergence reaches about 4°C in the northern regions in summer and less than 1-2°C in winter, in more southern parts it is close to freezing or freezing. At the Antarctic Convergence surface temperature rises steeply by 2°C.

2.3 The surface layer is 100-150 m thick. In the region close to the continent, no stratification can be observed as there is a mixing of the warm deep water with the water masses of the surface current.

2.4 Upwelling occurs in the area of divergence in a low pressure belt at about 65°S and also close to the continent.

The environmental conditions in the Antarctic Ocean have been summarised by Holdgate as follows:

"The Antarctic marine environment is thus a deep oceanic system with a strongly marked circulation. Upwelling brings nutrients into the surface water in considerable quantity. The light regime is seasonal, with abundant light for photosynthesis in summer, but virtually zero illumination in winter. The temperature is consistently low throughout the zone. As with many productive oceans, there is considerable turbulence in summer, but stability in winter under the protective ice cover. Granted tolerance for physiological adaptation to the low temperature, habitat conditions are favourable for life in summer, but owing to the low light intensities, become markedly less so in winter."

The following statements on primary production and plankton refer to the open parts of the ocean which are free of ice cover at least during part of the year. Along the edges of the continent where fast ice cover prevails most of the time living conditions are entirely different.

3. PRIMARY PRODUCTION

Primary production is limited due to the lower incident radiation caused by ice cover and long winters. On the other hand, there is a steady and rich supply of nutrients through vertical instability in many parts of the region.

During summer production can be exceptionally high, particularly in the northern parts of Weddell Sea, in the Drake Passage and in the neritic zone west of Graham Land. Some of the most recent figures based on C^{14} (at least partly in winter) experiments have been compiled by El-Sayed (personal communication) (Table 01). El Sayed (1970) also notes that productivity in oceanic waters is much lower than these high figures for the neritic zone.

Table 01 - Productivity values of Antarctic waters

Region	Chlorophyll (mg/m^3)	C^{14} uptake				Author
		mgC/m^3/hour	mgC/m^3/day	mgC/m^2/hour	gC/m^2/day	
Antarctic waters			9			Klyshtorin (1961)
Gerlache Strait	11.6					Burkholder and Sieburth (1961)
Bransfield Strait	3.6					" "
Antarctic (Indian sector)	0.15-0.6					Ichimura and Fukushima (1963)
Africa-Antarctic	0.17				0.03	Saijo and Kawashima (1963)
Australia-Antarctic	0.28				0.10	" "
Bransfield Strait					0.70	Mandelli and Burkholder (1966)
Gerlache Strait					0.86	" "
Antarctic waters (Atlantic sector)			13.30		0.145	Volkovinsky (1966)
Drake Passage	0.78	6.2		64.5	0.77	El-Sayed (1966)
Weddell Sea	0.61	2.4		30.4	0.68	" "
Bransfield Strait	0.86	11.8		142.4	2.76	" "
Gerlache Strait	6.27	13.1		101.4	1.31	" "
Marguerite Bay and Vicinity	2.73	2.9		25.0	0.46	" "
Bellingshausen Sea	0.36	0.8		13.16	0.24	" "

These figures refer to optimum summer conditions, the productive season being only about 120 days during which, however, daily duration of illumination is long. Even in summer, production under the ice is largely reduced to about 1% of the normal rate although standing stock of plants is rather dense under the ice (0.01 - 0.05 mgC/m^3/hour in McMurdo according to *in situ* C^{14} measurements by Bunt (1964) (cited from Carrick *et al.* 1964).

Figures for average annual production vary from 43 gC/m^2 (Currie 1964) to 84 gC/m^2 (El-Sayed 1968) and 100 gC/m^2 (Ryther 1963, for the total southern ocean). As the measurements tended to be somewhat concentrated in the richer areas, the overall mean for the Antarctic Ocean might be close to 50 gC/m^2

or even less. Although most parts of the Antarctic Ocean are not as productive as rich areas of the temperate zone, figures for abundance of phytoplankton are high, particularly off South Georgia, in Bransfield Straits, and in Weddell and Ross Seas, probably due to a lower turn-over rate. In open waters, it may reach 4 g/m^3 or more (according to Japanese findings) in summer, an average figure of 320 mg/m^3 is given by Holdgate for the total ocean.

El-Sayed (1965) in a paper at the 2nd International Oceanographic Congress compared recent figures on primary production in the Antarctic with earlier data by Steemann Nielsen (1954) on other regions of the world ocean. Although those first global estimates by Steemann Nielsen should be regarded as only roughly correct, El-Sayed's statements are worth quoting:

"It is interesting to note here that our average value of primary production for the inshore and offshore regions (0.89 $gC/m^2/day$) is about six times the average gross production over all the oceans (0.15 $gC/m^2/day$) estimated by Steemann Nielsen (1954). If we assume that our figure is representative of Antarctic waters, and using Mackintosh and Brown's (1956) estimate of the surface area south of the Antarctic Convergence as 2.38×10^7 km^2 in March, and 1.18×10^7 km^2 in September, the amount of carbon fixed in these two months are 21.24×10^6 and 10.53×10^6 tons of carbon/day, respectively. On a yearly basis (calculated here by multiplying the photosynthetic rate per hour, by the number of hours of sunshine per year) the production in Antarctic waters varies between approximately 0.45×10^{10} tons of carbon/year and 0.22×10^{10} tons of carbon/year, with an average of 0.33×10^{10} tons of carbon/year. This average represents about 20% of the average gross production in all the oceans (1.5×10^{10} tons of carbon/year), estimated by Steemann Nielsen (1954). Interestingly, the Antarctic waters, south of the Convergence, cover only about 5% of the world ocean. This means that per unit area the Antarctic waters are about 400% more productive than the rest of the oceans ..."

Standing crop as well as productivity of phytoplankton in the southern part of the region depends largely on the changes in the ice cover, due to which large seasonal and regional variations are observed.

4. ZOOPLANKTON AND INVERTEBRATE BENTHOS

Figures of standing crop vary considerably for different authors but all of them indicate that zooplankton abundance is high. In a general review of zooplankton standing stock throughout the world, Bogorov *et al*. (1968) found a band of high abundance - over 100 mg/m^3 - at around 60°S. This level is rather below the peak abundance in the northern coastal zones, and in upwelling areas. The nets used would under-estimate active animals such as euphausids, which may be relatively more common in the Antarctic. The highest figures were found close to the Antarctic Convergence and in the area of Graham Land and Scotia Sea. Zooplankton appears to be very scarce under the fast ice.

The total abundance of zooplankton varies very much from region to region. The Atlantic sector is richer than the others. During most of the summer zooplankton is concentrated in the upper 100 m; during winter in deeper layers, much of it is below 500 m. Seasonal variations in total zooplankton biomass in the water column of 0-1,000 m depth are moderate (Foxton 1956, Hopkins 1966, Voronina 1968).

F. Beyer (unpublished) compared biomass figures in Nansen net samples measured as displacement volume of plankton per m^2 water column. Those comparisons are based on Foxton's (1956) and Beyer's (unpublished) data on averages over larger parts of the Antarctic Ocean and on data from the Norwegian Sea. Displacement volume is 50 cm^3 to about 500 cm^3/m^2 in the Antarctic compared with 122 cm^3/m^2 in the Norwegian Sea. Taking minimum estimates of 50 cm^3/m^2, dry weight per m^2 would be 8-10 g/m^2. (If the annual production equals the average standing crop, 10 g dry weight per m^2 per year seems a conservative estimate.) Hopkins (personal communication) found an average zooplankton-micronecton abundance of 5.9 g dry weight/m^2. Quantitative estimation of zooplankton standing crop is made difficult by the patchiness of the distribution and the fact that the larger euphausids are active animals which may easily escape the nets being used. The latter factor makes the figures produced here under-estimates of the true standing crop. No good estimates exist of the proportion of euphausids in the total zooplankton. Voronina (personal communication) found 7.6% euphausids and 72.8% copepods in her samples, but her nets certainly under-estimated the euphausids. The proportion is probably highest in areas such as that round South Georgia, which are also centres of high total zooplankton abundance. Marr (1962) estimated the biomass of *E. superba* in the Weddell Drift as 30 g/m^2.

For fishery purposes information on euphausids in summer is particularly important. It has been described by various authors (reference should be made particularly to Marr (1962)). In summer, *Euphausia superba* is concentrated in the uppermost 10 m, abundance decreasing rapidly with increasing depth. The distribution is mainly confined to the areas close to the northern boundary of the east drift or at the fringes of the pack ice. The largest concentrations were found in the Weddell Drift, around South Georgia, South Sandwich Islands and South Orkney Islands and in the large area north of the Weddell Sea. Experimental fishing in the area of South Sandwich Islands by Soviet expeditions composed of factory ships and fleets of catchers equipped with large plankton trawls gave promising results. Catches of up to 6 tons of krill per hour of fishing were recorded (Burukovskii 1965).

There are no reliable data on annual production of zooplankton. The average life-span of most of the zooplankton organisms is unknown. The potential life-span of krill is 2 years (Marr 1962), but that of copepods is presumably less. Some animals will die or be eaten before becoming adult, so the average life-span might be one year or less. If it is one year, the total annual production might be of the same order as the average standing crop, i.e. 50 g/m^2 wet weight, mostly herbivores. Light conditions and grazing by zooplankton has been shown by Hart (1942) to be the main factor controlling phytoplankton in the Antarctic. The relatively high standing stock of zooplankton compared with phytoplankton is due to the longevity of the zooplankton organisms, which has the beneficial effect of storing organic matter over a long period and providing food for zooplankton feeders at a fairly constant rate.

An independent estimate of the lower limit to the annual production of the larger zooplankton, in particular krill (E. superba, that can be obtained from other euphausids) is the likely food consumption of the virgin stock of whales. According to Mackintosh and Brown (1956), the stock of whales in the mid-thirties was at least 340,000 specimens, their average weight was a little over 50 tons, the total stock was, therefore, about 18 x 10^6 tons. The virgin stock must have been somewhat higher as depletion of blue whales and humpback whales had already begun. The figure does not include sei whales, this is correct as sei whales feed preferably on other plankton. The virgin stock preying on krill might, therefore, have been not less than 20 x 10^6 tons. If it is assumed that for maintenance and growth the whales require an annual intake of food about three times the standing stock, the annual consumption 45-60 x 10^6 tons, of which at least two thirds would be krill taken in the Antarctic.

Alternatively, one might suppose from the few published observations on stomach contents of large baleen whales that a whale of 50 tons may take 1 ton of krill per filling of its stomach. One filling per day seems a low estimate. The feeding season of whales in the Antarctic is about 120-150 days. It has been found a varying percentage of whales with empty stomachs, which might bring the number of days of effective feeding average down to about 100 days. The amount eaten per year and whale would then be about 100 tons. The total intake of the virgin stock of krill eating whales which might have been between 4-500,000 specimens was 40-50 x 10^6 tons.

Zenkovich (1968 and unpublished communication kindly provided by Dr. Bogdanov) gave the following estimates of the consumption of krill and other plankton crustaceans by whales in the Antarctic:

	Initial stock	Daily ration (tons)	Feeding season (days)	Total consumption 10^6 tons
Blue whales	100,000	4	120	50
Fin whales	200,000	3	120	72
Humpback whales	50,000	2	120	12
Sei whales	75,000	1.5	100	12

This total figure of 146 x 10^6 tons krill eaten annually by whales would be an over-estimate if the whales fill their stomachs less often than the four times a day assumed by him. On the basis of his figures, one has to assume a very low conversion efficiency (in the steady state growth plus recruitment will be equal to natural deaths, or 5-10% of the population, i.e. 0.7-2.0 x 10^6 tons, which is only 0.5-1.5% of the consumption). However, his estimate of the unfished whale stocks appears low. The report of the Committee of Three scients (IWC 1964) gives an initial population of blue whales of rather over 200,000 animals. Thus his estimate of total consumption is probably not too low.

As we have to assume also other predators on krill besides large baleen whales, those figures based on their feeding should be under-estimates of total krill production. The population of crabeater seals which has been estimated as 2 x 10^6 tons might take another 6-10 x 10^6 tons of krill. The amount of krill consumed by birds and Weddell seals is comparatively small. The ecological importance of krill eating fish is unknown in the Antarctic. In summer shoals of fish feeding on krill close to the surface occur frequently off South Georgia (Olsen unpublished information) and in the Scotia Sea (Permitin 1968).

These figures suggest that the consumption of euphausids by large mammals is well over 100 million tons, or 7% of the estimated total zooplankton production. This figure is equal to the observed percentage of euphausids in net samples, which is certainly an under-estimate of the true percentage in the zooplankton. It may be that the actual production of euphausids is as high as 200 million tons. Gulland (1970) suggests a slightly lower figure, due partly to a confusion between dry weight and wet weight in the estimates of zooplankton standing crop.

Only a small fraction of this could be relatively easily harvested by man, the rest are too widely scattered or otherwise inaccessible. Fishing operations are limited to about 4 months during which concentrations at the surface are high (December to April) and are confined to the area off Antarctic Peninsula, South Georgia and outer Weddell Sea. As krill is concentrated in eddies and on boundaries of water masses, hydrographical surveys would facilitate the search of the catching fleets.

During the SCAR Symposium on Antarctic Ecology held in Cambridge in July-August 1968, there was considerable discussion of the resource potential of the krill, and of the problems raised (a) by possible increase of other krill eaters - birds and seals following the reduction in the whale stocks, and (b) the influence of a possible fishery on the krill stocks. There was a lack of relevant data; in particular there was no direct evidence of any of the alternative krill consumers having increased. Also most of these are confined to a greater or lesser extent to the waters close to the breeding places on land or on ice. Even less is known about the possible reaction of krill stocks to exploitation, but if exploitation is limited to substituting for whales, the above figures would appear to provide a safe lower limit to the potential harvest (less a small amount for the present consumption by whales).

On the shelf of Antarctica and its islands a very rich bottom fauna is found. Average figures of 400-500 g/m^2 on the continental shelf in 100-500 m depth (Belyaev 1958, cited by Holdgate 1967). Only in greater depth abundance decreases to values comparable to those found at the deep sea floor of other oceans ($\simeq 1$ g/m^2).

The bottom fauna consists mainly of sessile or sluggish and slow-growing organisms such as sponges, bryozoa, echinoderms, gorgonaceae and tunicates which are rather dead ends of the food chain in terms of possible harvest by man. Belyaev estimates that 60% of the benthos is not directly available as food for other organisms.

5. ECOLOGICAL POTENTIAL OF PRIMARY PRODUCTION AND ECOSYSTEMS FOR FISH PRODUCTION IN THE AREA

From the biological point of view the Antarctic Ocean is characterised, not by exceptionally high annual means of primary production, but by a high and stable standing crop of zooplankton which, however, is only accessible to whales and other epipelagic predators in summer. In winter it concentrates in deeper layers. Warm blooded predators concentrate on euphausids which make up half of the biomass of zooplankton and which are characterised by their longevity, their large size and their tendency to form patches in summer in the uppermost few metres.

A striking feature is the absence of information on consumers of the smaller zooplankton. Copepods make up a large part of this community, but there are no observations on the occurrence of quantities of pelagic fish such as herring or capelin which occur in Arctic and sub-Arctic waters. This may be due to the absence of suitable spawning areas, and the equivalent ecological niche is occupied by squids, or other animals too active to be caught by most scientific equipment. These may form a large resource. (The benthos forms a dead end for much of the food chain which binds a considerable part of the organic matter for a long time). With the depletion of the large stocks of baleen whales part of the zooplankton became also a "dead end" which, however, might be exploited by man in a direct way.

6. FISH STOCKS AND FISHERIES

6.1 Statistics

There is virtually no commercial fishing for fish and squid in the Antarctic Ocean. Some records are available from scientific trials, particularly for taxonomic and physiological purposes. Statistics on whaling are fairly accurate and detailed, collected by the International Whaling Commission (IWC).

6.2 Whaling

The history of Antarctic whaling, its rise and decline, is well known. The details are given in the various reports of the International Whaling Commission, especially the reports of the special Committee of Three (later Four) Scientists (IWC 1964). Antarctic pelagic whaling developed after the first world war. Catches of blue whales reached a peak of 29,400 animals in the Antarctic during the 1930/1 season, and since then steadily decreased until blue whales were given complete protection by IWC in 1964. Catches of fin whales reached an inter-war peak of 28,000 animals in 1937/8. The post-war catches were held, under regulation, to a rather steady level of around 25,000 animals until 1961/2 until declining stocks, and belated measures to reduce the quota, caused a rapid decline to 3,000 animals in 1968/9. As the fin whales declined, the expeditions turned more to sei whales; catches of these were nearly 20,000 animals in 1964/5, but with a reduced quota only 5,770 in 1968/9.

Catches of humpback whales have been spasmodic, occasionally reaching over 2,000 animals in the Antarctic, though they have been protected since 1963. Unlike the other large baleen whales, which are only very lightly exploited during the southern winter, when they migrate, outside the Antarctic, appreciable numbers of humpback whales from the Antarctic stocks have been caught along the coasts of Africa and Australasia.

The statistical information on whaling generally gives the catches only in terms of numbers of animals, though the weight of the various products is known. Data on the weight of individual animals have been given by Crisp (1962). These were as follows:

Blue whale	84 tons
Fin whale	50 tons
Humpback whale	33 tons
Sei whale	22 tons

From these figures the whale catches, in terms of weight, may be estimated to have reached a peak of 2.5 million tons in 1930/1, to have been fairly steady at a little under 1.5 million tons in the 1950s, and been about 300,000 tons in 1968/9.

The present stocks, especially of blue and humpback whales, are very heavily depleted, and would require several decades to recover to a level at which each could give its maximum sustainable yield. These yields, and corresponding stock sizes, have been estimated to be as follows (from IWC 1964, and recent annual reports).

	Stock at optimum		Annual yield	
	number	tons x 10^{-6}	number	tons x 10^{-6}
Blue whales	100-125,000	8-10	6,000	0.5
Fin whales	150-200,000	7-10	20,000	1.0
Sei whales	60-70,000	1.3-1.5	4,500-5,600	0.1
Humpback whales	tens of thousands	(0.5)	ca 1,000	0.03

6.3 Fishes

According to Holdgate, 60 pelagic species of fish and 90 benthic species have been recorded. These figures probably include findings in sub-Antarctic waters. Little is known about the abundance of these fish. In the rich area of the Pacific sector of the convergence, Hopkins (personal communication) found average dry weights of 0.5 g/m^2 mainly of myctophids.

In the area of South Shetland and South Orkney Islands pelagic gadoids (Micromesistius australis) and Patagonian hake (Merluccius hubbsi) migrate in summer from the North feeding on krill (Mikheev 1965). Soviet mid-water trawling yielded up to 5-10 tons per 2 hours' haul; myctophids are abundant south of the convergence. Benthic fish were not found by the Soviet vessels in commercial quantities, but there might be exploitable stocks of limited size around the island where Nototheniidae and Chaenichthyidae are the prominent families. As spawning sites for bottom spawners are limited in area in the Antarctic region bottom spawning stocks are limited in their abundance. This is in contrast to the Arctic and sub-Arctic region where bottom spawning herring and capelin are the most important pelagic fish; Olsen (1954) and unpublished data) has measured the increment of about 0.6 kg/year in Notathens rossii marmorata off South Georgia in 1950/1. The growth of these fish compares well with that of many Arctic and sub-Arctic food fish, e.g. gadoids.

In other areas, the distribution and abundance of fish eggs and larvae have been used to provide a first rough estimate of the distribution and abundance of commercial sized fish. No extensive published material appears to exist about fish eggs and larvae in the Antarctic, but Hart (personal communication) states that fish larvae were rare in very extensive plankton hauls made by the Discovery investigations. This suggests that the fish resources, in the Antarctic as a whole, are comparatively small.

There are indications from the stomachs of elephant seals, sperm whales, and penguins that squid are a major element of the pelagic fauna in the Antarctic.

Far more information is needed for even a rough estimate of the fish potentials of the region. It seems particularly important to look into possible resources of the area of the Antarctic Convergence and on the Kerguelen Shelf. This area is relatively productive and provides tolerable temperature conditions.

Crabeater seals provide a considerable resource which is virtually untapped, though an exploratory voyage by a Norwegian sealer for skins had promising results. Rough estimates of stock size are 2×10^6 tons ($5-8 \times 10^6$ seals of 300 kg each); the maximum sustainable yield will presumably not exceed 10% of the virgin stock. Exploitation of the bird population and of Weddell seals would not be a large source of protein.

7. COMPARISON OF ESTIMATES OF THE MAXIMUM SUSTAINABLE YIELD WITH ECOLOGICAL POTENTIAL AND PRESENT FISHERIES

The total primary production of the Antarctic Ocean is of the order of $1-3 \times 10^9$ tons carbon $\approx 20-60 \times 10^9$ tons wet weight, but under the assumption that krill production amounts to 150×10^6 tons and that the other herbivores are similarly productive annually production of planktonic herbivores is only 300×10^6. This implies a very low ecological efficiency (0.5-1.5%) between the primary and secondary production. Possibly, as noted in section 4, the secondary production is under-estimated. Also although grazing is locally very intensive, a considerable part of the phytoplankton may not be used by herbivores. Compared with these figures of primary and secondary production, exploitation by man is at present very poor (ca 500,000 tons whales). The relatively simple food chain would permit a much higher exploitation.

The biggest resource is the krill. A sustained yield of tens of millions of tons is clearly possible, and the potential may be very much greater. Under proper management about 2 million tons of whales and seals could be harvested. The promising fish resources appear limited to the arc of islands round the Scotia Sea; catch rates might be high, but the total area is not very large. Squid resources might well be large.

8. REQUIREMENTS FOR IMPROVED ESTIMATES

Apart from those concerning whales, which are reasonably accurate, all the estimates of potential resources in this review are highly speculative. The main reason is that, again with the exception of whales, the resources are unexploited. The statistical and other data normally available from established fisheries are absent, nor is it known what would be the reaction of exploitation of important resources such as krill. Reliable quantitative estimates of the Antarctic resources (closer than say within a factor of perhaps two to five), will probably not be obtainable until exploitation of them has started on a significant scale. Some improvements in the present very rough estimates could, however, be obtained earlier, though even these are sufficient to show the potential value of the Antarctic seas.

The present data on primary production are good enough to show that the Antarctic is highly productive. Improved estimates of total primary production would probably not, with the present great uncertainty concerning the quantitative relations between primary, secondary and later production lead to greatly improved quantitative estimates of the resources (the factors of 10% or 15% often used are little more than guesses). Improved data on the variation of primary production in space and time would be useful in predicting the likely distribution of the resources, and improving the extrapolations from the South Atlantic sector when most observations have been taken.

Quantitative data on the zooplankton are scarce, and further data would certainly improve the estimates. For instance, the estimates used of the relative quantity of krill and other zooplankton could certainly be improved, as could the estimates of standing crop of krill, though the choice of suitable gear and the appropriate sampling patterns to take into account the very uneven distribution raise larger problems.

The present knowledge of the qualitative distribution of the potential resources could certainly be greatly improved even before quantitative measures are possible. The fish (or at least bottom fish) resources may be limited to the Scotia Sea area, but other resources occur all round the Antarctic, though most records are in the Atlantic sector. The krill distribution may be reasonably well covered by normal collection of plankton, plus direct observations of surface swarms, but other possibly large resources, e.g. squid, may need special techniques for adequate study of their distribution.

INTRODUCTION

Previous chapters of this report have reviewed the resources over and adjoining the continental shelves of each major ocean area. Since the oceanic resources are similar (even down often to the species level) in all oceans, and the data are inadequate for many parts for separate analysis, all the open oceans of the world are treated together here. The exception is the Antarctic, which is dealt with separately.

The area covered may be defined by subtraction - i.e. excluding the shelves and upper part of the continental slopes, the Arctic Ocean (whose production is negligible) and the Antarctic south of the Antarctic Convergence - i.e. it is about 80-85% of the total area of the oceans, (290-310 x 10^6 km^2).

1. HYDROGRAPHY

Since the areas considered cover all the major current systems of the world, it is not possible to give an adequate summary here, and the reader is directed to one of the general oceanographic text books. Mention is made in other sections of certain features important to the discussion, particularly to the upwelling areas and the equatorial currents.

2. PRIMARY AND SECONDARY PRODUCTION

The primary production in the open oceans is highly variable, while observations are generally few and scattered (for example, virtually none in the Southeast Pacific other than near South America). Thus estimates of total production and of its distribution must for the present be rather rough (Steemann Nielsen 1954). Steemann Nielsen and Jensen (1957) made one of the first estimates of the total world productions; more recently, Koblentz-Mishke (1965) has made a more detailed study of the Pacific, summarising all data available to her. She also derived a relation between the rate of production per unit volume at the surface to production throughout the water column per unit area. Over much of the warmer parts of the open ocean production is very low, though because of the great areas concerned the total production is high. There are, however, two main regions of higher production - the upwelling areas off the western margins of the continents and in the equatorial current systems (most marked in the Pacific). The northwestern part of the Indian Ocean also appears to have above average production. The data in the latter area, mainly collected during the Indian Ocean expedition, have been summarised by Wooster *et al.* (1967). Though data are very sparse in summer (5 observations in June-July-August), production seems high in autumn but low in spring. Cushing (1969) has reviewed the data for the major upwelling areas (equatorial zone and western continental boundaries). From the data of Koblentz-Mishke and Cushing, the total production of various areas in the Pacific can be set out as follows:

Table P1 - Estimated total primary production in the Pacific

Author	Region	Area (km^2)	Mean produc. mgC/m^2/day	Total produc. tons C
Koblentz-Mishke (Table 4)	1. Tropical Oceans	90 x 10^6	76	2.49 x 10^9
"	2. Tropical/temperature transition and periphery of equatorial divergence	33 x 10^6	135	1.64 x 10^9
"	3. Temperate oceanic; equatorial divergence	31 x 10^6	250	2.85 x 10^9
"	4. + 4a. Temperate coastal; convergence off Central America	10 x 10^6	288	1.10 x 10^9
"	5. Neritic	0.24 x 10^6	650	0.058 x 10^9
	Total Pacific	164 x 10^6	-	8.14 x 10^9
Cushing (Table 1)	Coastal upwelling (California-Peru etc.)	2.2 x 10^6	200-1,000	0.24 x 10^9
"	Equatorial upwelling	26 x 10^6	150	1.75 x 10^9

The table shows a fair degree of agreement, but Koblents-Mishke's tabulation groups together areas with quite different fish resources. For the purposes of this report, it will be assumed that the temperate oceanic region and the equatorial divergence account for one third and two thirds respectively of Koblents-Mishke's group 3 (this gives a rather smaller area of high production along the Equator than Cushing, though the difference may be only a matter of definition) that her group 4 can be divided into 22% sub-tropical coastal upwellings (California, Peru, etc., to agree with Cushing), and the other 78% equally between the temperate and sub-arctic coastal waters (Japan, Gulf of Alaska, British Columbia), and the tropical water off Central America. This gives the following regions, with approximate areas (in millions of km^2) and estimated total primary production including the production in the adjacent seas (Bering, Okhotsk, Japan, Yellow and China Seas) taken as 150 $gC/m^2/year$.

(a) neritic	0.24×10^6 km^2	0.06×10^9 tons C
(b) sub-tropical coastal upwelling	2.2×10^6 km^2	0.24×10^9 tons C
(c) temperate and sub-arctic coastal waters	3.9×10^6 km^2	0.44×10^9 tons C
(d) waters off Central America	3.9×10^6 km^2	0.44×10^9 tons C
(e) equatorial upwelling	20×10^6 km^2	1.90×10^9 tons C
(f) temperate oceanic waters	10×10^6 km^2	0.95×10^9 tons C
(g) transitional oceanic waters	33×10^6 km^2	1.64×10^9 tons C
(h) tropical oceanic waters	90×10^6 km^2	2.48×10^9 tons C
(i) bounding seas	15×10^6 km^2	2.25×10^9 tons C
Total Pacific	180×10^6 km^2	10.39×10^9 tons C

Of these, (a), (b), (c) and (i) are discussed in the regional chapter and the present chapter is only concerned with the rest. These latter have a combined production of 6.4×10^9 tons C, or over 90% of the total excluding the production in the adjacent seas - Bering Sea, Japan Sea, South China Sea, Java Sea, etc.

Similar convenient compilations of the detailed studies made in the Atlantic or Indian Ocean are not available, but probably the same general conclusion holds true - the highest production per unit area occurs near the coasts, but because of the difference in extent, the bulk of the total production occurs in the oceanic regions.

3. ZOOPLANKTON

The distribution of the standing crop of zooplankton, as weight or wet volume per unit volume sampled, has been summarised for the Pacific by Reid (1962) and for the world by Bogorov *et al.* (1968). This distribution is very similar to that of primary production, with greatest density in coastal waters, in the equatorial zone of the Central Pacific, and the northern parts of the Pacific and Atlantic Oceans. The presentation probably under-estimates the relative production per unit surface area in the warmer waters, and in the ocean generally, first because the rates of growth, mortality, etc. are likely to be higher in warmer water (giving a higher ratio of production to standing crop) and second because the zooplankton extends to a greater depth in the open oceans (giving a greater density per unit surface area for a given volume density).

With this reservation, it is noticeable that the zooplankton density on all the great fishing grounds (Northeast and Northwest Atlantic, round Japan, off Peru, etc.) is high (>100 mg/m^3 according to Bogorov *et al.*) or very high (>200 mg/m^3). The latter density is only reached elsewhere in the open oceans in narrow strips of the Pacific equatorial system, and over 100 mg/m^3 only occurs in limited areas (equatorial bands of all oceans), in the northwestern Arabian Sea, in the northern Pacific and Atlantic, and in the Antarctic.

More detailed studies of certain areas show that there can be quite an abrupt change between areas of high and low zooplankton. For instance the SHELLBACK and EASTROPAC expeditions and other data in the eastern tropical Pacific found very high volumes (over 500 cc wet volume/

1,000 m^3) off Ecuador towards the Galapagos Islands, and nearly as high along the coasts from Costa Rica to southern Mexico, but very low values offshore from Baja California (Holmes *et al.* 1957, Blackburn 1966).

As pointed out by Reid (1962), precise comparison of zooplankton data from a number of sources is difficult because of differences in the nets used and in their catching efficiencies. Most of the data he reviewed were collected with the CCOFI-POFI net; this, and similar nets, have a relatively large mesh (0.25 - 0.55 mm aperture), and thus miss some of the smaller animals which can pass through the meshes. Also some of the more active planktonic animals may escape from the front of the net. With this reservation, Reid estimated the total standing crop of the larger zooplankton in the upper 150 m of the Pacific as 10^9 tons wet weight. This will be $\frac{1}{T}$ times the annual production, where T is the mean life-span of the animals.

Cushing (1969) used, in a similar calculation, the mean generation time - the time from egg-laying to reaching the adult stage - of copepods, deduced from data of Marshall and Orr (1955) and McLaren (1965). He estimated the duration as between 30 and 60 days, according to temperature, giving generally from 3 to 6 generations, depending on temperature, and the duration of the upwelling season (assuming no growth outside this season). The generation time will be an upper limit to T, so that the annual production of copepods in the warmer parts of the world is probably from 5 to 10 times the average standing crop. Though a major element of the zooplankton in most areas, copepods are not the only small zooplankton animals; in the eastern tropical Pacific, they make up only 20% of the total zooplankton (Mais and Jow 1960). If the other animals - tunicates, chaetnognaths, euphausids, etc. - have the same average life-span, then the annual production of small zooplankton in the Pacific, excluding adjacent seas, is around 5-10 x 10^9 tons wet weight Taking carbon as 10% of the wet weight, this is some 7-12% of the primary production, in fair agreement if the zooplankton is herbivorous and the ratio of the production at successive trophic levels is around the commonly assumed values of 10-15%. However, the smaller zooplankton may have been under-represented in the net samples, while some of the animals are wholly or partly carnivorous, so the agreement may be fortuitous.

4. THE FISHERIES

At present only the larger and more valuable animals (whales, tuna, salmon) are exploited at more than a relatively short distance from the continental shelves. Though salmon, particularly in the Pacific, feed on the open oceans, and make most of their growth there, the most critical period of their life is in the rivers, and the salmon resources are, therefore, discussed in the appropriate coastal section.

4.1 Whales and dolphins

The larger baleen whales (blue, fin, humpback and sei), which are largely zooplankton eaters, are mainly exploited in the Antarctic, and in the North Pacific, and a few are caught in the North Atlantic (see Appendix Table P1). The story of the depletion of whale stocks in the Antarctic is well known, and no great increase in catches from the present (ca 3,500 BWU) can be expected for a long period. These 3,500 BWU produce about 60,000 tons of oil, 130,000 tons of meat, and 35,000 tons of meal and other by-products. Under proper management the Antarctic could probably produce about 17,000 BWU from all species combined, or around 850,000 tons of various products, equivalent to perhaps 1.5 million tons live weight.

The situation in the North Pacific is not quite so gloomy; the blue whales have been very seriously depleted, and have had to be given complete protection; the fin and sei whale stocks are probably respectively rather below, and slightly above, the levels giving the greatest sustained yields, which are about 1 - 2,000 whales of each species. Small quantities of the larger baleen whales can also be taken in the North Atlantic, though the right whales and probably also the blue and humpback whales have not yet recovered from earlier over-exploitation; also those in the Arabian Sea may be separate stocks. Altogether, the larger baleen whales outside the Antarctic might provide, if properly managed, around 1,500 BWU, or 140,000 tons live weight.

Sperm whales which feed largely on the bigger squids, are found throughout the oceans, though the young whales and females are confined to the warmer waters (roughly between 45°N and 40°S).

There is some separation of stocks; for instance three distinct breeding groups have been distinguished in the North Pacific, though the larger males from these groups mix together in the higher latitudes.

Three distinct fisheries occur - from land stations (including Korea, Japan, Chile, Peru, Australia and South Africa); pelagic whaling in high latitudes; and pelagic whaling elsewhere. The second of these is directed mainly for baleen whales, ans sperm whales are taken incidentally or outside the baleen season; the catches of sperm whales have not been very high, and are almost entirely males. Pelagic whaling by factory ships, outside the Antarctic and the northern North Pacific, which is the modern successor of the old New England open boat whaling, occurs only irregularly, usually by vessels returning from the Antarctic. Catches can be high, often of small animals of both sexes.

No precise assessment can be made as yet (IWC/FAO 1969). Some stocks exploited by local shore-based operations have certainly been over-exploited. Probably the average yield in the last few years - ca 25,000 animals - is around, or possibly even above, the amount that can be sustained indefinitely. This is equivalent to a live weight of around half a million tons, and a production (at 5 tons per animal) of 125,000 tons of oil.

A number of medium sised whales are exploited - minke whales (*Balaenoptera acutorostrata*) off Norway, and a few off Japan; pilot whales (*Globicephala melaena*) in the Faroe Islands and Newfoundland; a few killer whales (*Orcinus orca*); and bottle-nose whales ____________ ____________. Exploitation is very localised, and total catches amount to no more than 5-10,000 whales annually. Certainly the world catch could be increased several-fold by extending exploitation to other regions, but equally certainly the total production will never be very large - even a ten-fold increase (which might be an upper limit) would yield less than half a million tons.

Finally, among marine mammals, the smaller cetaceans - porpoises and dolphins - offer a potential source of meat. They are undoubtedly widespread, but are both conspicuous, and attracted to ships and therefore possibly not as numerous as the frequency of observations might suggest. As for whales the sustainable yield will only be a small fraction of the standing crop. Also the animals are all active predators on fair sised fish, and thus at the top of the ecological pyramid. Thus the potential yield may not be very large (perhaps half a million tons might again be a reasonable upper limit), and in practice large-scale harvesting may well not be introduced, since it could not be done without some cruelty, and thus is likely to be strongly opposed by the general public.

4.2 Tunas

The major tuna fisheries (see Appendix Table P2) are based on 6 main species - albacore (*Thunnus alalunga*), bigeye (*T. obesus*), bluefin (*T. thynnus*), southern bluefin (*T. maccoyii*), yellowfin (*T. albacares*), and skipjack (*Katsuwonus pelamis*). In addition bonito (*Sarda* spp.) support local fisheries, and the catches of the longline tuna vessels include important quantities of billfish (Histiophoridae - marlins, etc.). Other smaller tunas and related species which are not at present caught in quantity include the frigate mackerel (*Auxis thazard*), little tunas (*Euthynnus* spp), and the blackfin (*T. atlanticus* and *T. tongoll*)(Collette and Gibbs 1963).

Tunas are active, cosmopolitan, predatory species (for comprehensive reviews see particularly the papers in the report of the World Scientific Meeting on the Biology of Tunas and related Species. FAO (1963). Some (albacore, bluefin) are known to carry out trans-oceanic migrations. The albacore in the North Pacific is probably a single stock with the younger fish being caught in cooler North Pacific waters, and the older fish occurring in North Equatorial Current where they spawn (Otsu and Uchida 1963, Suda 1962). The south Pacific albacore are probably separate, and the same separation probably also forms a northern and southern stock in each ocean. The degree of separation if any, between the stocks in the southern hemisphere is unknown, but movement occurs round Australia (Shomura *et al.* 1967).

The more tropical yellowfish does not seem to move so much, and within each ocean there are probably distinct stocks within its more or less continuous equatorial distribution (e.g. Joseph *et al.* 1966).

The tuna fisheries can be conveniently divided into two groups - the longline fisheries of Japan (and now also the Republic of Korea and China (Taiwan)), which have spread to all areas of the world (Suda and Schaefer 1965); and the more local surface fisheries on the schooling fish using live-bait, purse seine, etc. The longline fishery takes mainly large fish, while the surface fisheries take mainly the smaller fish - though the modern purse seines take appreciably bigger fish than the live-bait vessels, and where surface catches are high the numbers of bigger fish caught may be greater than the numbers taken in the longline fisheries in the same area.

4.3 Stock Assessment

The best studied group of tuna are the yellowfin in the eastern tropical Pacific (Schaefer 1957, 1967 and reports of the IATTC). Though there are some doubts concerning the precise yield that can be taken, and of the corresponding fishing effort, there is no doubt that the stock is close to being fully utilised and that the sustainable yield is about 100,000 metric tons. Very recently catches have been above this level, possibly due to an expansion westward onto more or less separate stocks.

The state of the stocks in the Atlantic and Indian Oceans has been most recently reviewed by the FAO Working Gooup Meeting in Miami (FAO 1968). This concluded that no further expansion of longline catches of yellowfin, bluefin or albacore was possible, though bigeye catches could be expanded slightly. A similar conclusion was reached by Rotschild and Uchida 1968) regarding the longline fishery for albacore, yellowfin and bigeye in the Paqific. Silliman (1966) estimated the bigeye potential in the Pacific as only 78,000 tons, though the catch statistics suggest this may be an under-estimate. The potential to the longline fishery of the various species has been summarised in Table P2 (assuming no change in the present - 1960-5 - pattern of surface fishing).

Table P2 - Estimated potential annual catches of tuna by longlining ('000 tons)

Species	Pacific	Indian Ocean	Atlantic
Yellowfin	60	30	40
Bigeye	80	15	25-30
Albacore	50+	15	40
Bluefin	(b)	35-40(b)	15(a)
TOTAL	190+	95-100	120-125
Width (degrees along Equator)	150	55	60
Tons/degree	1,200+	1,800	2,000

Notes - (a) Includes catches of large tuna in the coastal, trap, fishery of Mediterranean countries

(b) Pacific included with Indian Ocean (southern bluefin)

For comparison the width of each ocean, as measured by the number of degrees along the Equator, is also given in the table. There is a fair consistency between the size of the oceans, and the total longline potential (about 1,200 - 2,000 tons per degree), giving some support to the assessments, though the equatorial Pacific has a rather higher primary production, and so might be expected to have a higher yield of tuna.

The estimation of total yield must take into account the surface fisheries on smaller fish. For the Pacific stocks a detailed discussion of the possibilities of increasing the yields by adjusting the size at first capture has been given by Rothschild and Uchida (1968). They conclude that the data, including information on stock separation, were not good enough for firm conclusions, but probably more fishing on the medium sized fish could increase the sustainable yield. The Miami Working Group concluded for Atlantic yellowfin, on the basis of rather inadequate data, that the optimum size at first capture, even at high fishing rates, was less than the size of recruitment to the longline fishery and that the presence of a surface fishery would increase the total yield, but decrease the yield of the longline fishery.

The figures in Table P2 should therefore, to give estimates of total potential, be adjusted (a) to increase the total by the catch of the surface fisheries existing in 1960-5, whose effects on the longline fisheries are already included; and (b) to take into account the effect on the net total catch of new surface fisheries, or the intensification of present ones. (a) presents few problems: the only substantial surface fisheries for the larger species of tuna at the time were the surface yellowfin fishery (mainly by the USA) in the East Pacific (ca 80,000 metric tons/year), US and Japanese fishing for albacore in the North Pacific (ca 50,000 tons), French and Spanish albacore (40,000 tons) and various countries fishing for bluefin in the Northeast Atlantic and Mediterranean (ca 25,000 tons). The fishery for yellowfin and bigeye off tropical west Africa was just developing, but probably not sufficient to affect the longline catches significantly in the period considered.

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* Inter-American Tropical Tuna Commission

Of these surface fisheries, only for the East Pacific yellowfin is it believed that no great increase in gross catch is possible. The Miami Working Group made some rough estimates of the effect of fishing on the Atlantic yellowfin stocks, and concluded that the stock was moderately heavily fished, but that a moderate increase in fishing could give some increase in yield. The statistics examined covered the period up to 1966, during which the effort had been steadily increasing. The average surface catch in the last three years (1964-6) was 30,000 tons; perhaps this might be increased to as much as 50,000 tons by a doubling of effort. This would cause a decrease in the longline catch; the Miami report suggested that a surface catch of 30,000 tons would give a net addition to the total catch of probably 5-10,000 tons (more extreme limits would suggest a loss or an increase of 15,000 tons). The actual figure would depend on the sizes of fish caught in the surface fishery; if the size of first capture is not allowed to become too small the surface fishery could increase the total catch by 10,000 tons above the 40,000 tons in the established (1958-64) longline fishery. The potential totals yellowfin catches from the Atlantic may therefore be estimated at 50,000 tons plus also the surface catches (ca 10,000 tons) already existing in 1955-62 (which would have affected the longline catches) a total of 60,000 tons.

The studies on the Atlantic yellowfin showed clearly that the long-term effect of the surface fisheries depended critically on the growth and natural mortality of the smaller fish, and the actual sizes taken in the surface fisheries. The former are not at all well known. Although the more probable rates for the Atlantic yellowfin suggested a gain from increased surface fishing, possible, if improbable, combinations of growth and natural mortality would indicate a loss.

The possibilities of increasing the sustained catches from increased surface fishing are even more uncertain in other areas, and for other species. Hayashi (1966) showed that, for one combination of mortality and growth rates, the greatest catch of southern bluefin was taken at an age of first capture of 7 years. It is not feasible to examine here all the possibilities.

One assumption that can be made is that the potential gain from increased surface fishing is, for all species, the same as that for the Atlantic yellowfin. The resulting estimates are set out in Table P3. This suggests a potential increase of a little over 100,000 tons. The true value probably lies between zero and 200,000 tons, but much more investigation is required on the population dynamics of each individual stock.

Table P3 - Estimated total potential of large tuna species, assuming a moderate increase possible from increased surface fishing

Species	Pacific				Indian Ocean				Atlantic			
	(A)	(B)	(C)	Total	(A)	(B)	(C)	Total	(A)	(B)	(C)	Total
Yellowfin	60	70	15(b)	145	30	-	10	40	40	10	10	60
Bigeye	80	-	20	100	15	-	5	20	25-30	-	5	30-35
Albacore	50+	50	10	110	15	-	5	20	40	40	10	90
Bluefin	30(a)	7	8	45	25	-	5	30	15	25	5(c)	45
TOTAL				400				110				225

Notes - A = Longline potential from table P2
B = Annual catches in existing (pre 1965) surface fisheries
C = Net sustainable addition to total catch from new or increased surface fishery
(a)= Rough estimate, including unknown potential of Southeast Pacific
(b)= Western Pacific only
(c)= South Atlantic

The figures in the table are inevitably rough, and in some cases, e.g. for bigeye in the Pacific it is not known whether intense fishing on the medium size fish is practicable, let alone what the effect of such a fishery on the total yield might be. They have been included to complete the picture of the potential of these species of fish, and are probably as accurate as can be obtained at present.

4.4 Billfish

No detailed assessments have been made of the state of the stocks of billfishes. The catches have declined since a peak in 1965, and it is probable that, like the larger tunas, they are about fully exploited, and that the recent catches, ca 75,000 tons, are as much as can be harvested.

4.5 Smaller tuna: Skipjack

Though distributed widely on all tropical waters, and apparently common over much of its distribution, large catches of skipjack are taken in only two areas, southwest of Japan, by Japanese pole and line vessels, and on the eastern tropical Pacific, mainly by US purse seiners (Waldron 1963, Sette and Rothschild 1966). Smaller fisheries occur around Hawaii and elsewhere.

The population dynamics of the East Pacific skipjack have been reviewed by Joseph and Calkins (1969). The population structure of the Pacific skipjack is not known, though from the distribution of larvae (Matsumoto 1966) and tag returns it is fairly certain that some if not all the skipjack fished on the East Pacific migrate into the Central Pacific to spawn. The Central Pacific fish may consist of mixtures of fish from the East Pacific, and of local, and partly West Pacific fish. The loss rate of fish from the East Pacific fisheries therefore includes a substantial elemeny of emigration, as well as fishing and natural mortalities (plus tag shedding in the case of tagged fish).

Joseph and Calkins analysed the state of the stocks both by correlating catch per unit effort (c.p.u.e) and effort, and by estimating mortality and growth rates. They concluded that there was no correlation observable for either the southern or northern areas (though Broadhead and Barrett 1964, had found a suggestion for reduced c.p.u.e. with increasing effort in the southern area). However there are certainly big fluctuations in the availability of skipjack for non-fishery causes which may obscure any correlation. Also skipjack is only the second choice species (after yellowfin) for most of the vessels so that a positive correlation might be expected - skipjack effort being high when skipjack are particularly abundant (or available).

The lack of any measurable decrease in average c.p.u.e. with increasing effort is inconsistent with the analysis based on mortality and growth rates (fishing mortality being derived mainly from tagging). This latter suggests that fishing is now sufficiently intense for the possible increase in yield per recruit to be only from 10% to a little over 100% above the present, depending on the growth, and the area of fishing. However, even if the maximum catch is being approached, and the average c.p.u.e. is no more than half what it would be with no fishing, the dominant factors in determining fishing success in any one particular season remain environmental.

Joseph and Calkins remark that the two analyses are not strictly comparable since one is of total yield, and the other of yield per recruit. Few analyses have yet been made of stock-recruit data for tuna. Schaefer (1967) has deduced what the shape of the stock/recruitment curve for yellowfin must be if both the c.p.u.e./effort and the yield per recruit analyses are valid. If reduced adult stock does result in reduced recruitment, then the yield per recruit analyses will over-estimate the yield from high levels of fishing. Recently Davidoff (1969) has plotted stock against recruitment for the East Pacific yellowfin. There is no statistically significant relation but there is a fair suggestion of increasing recruitment with decreasing stock at least over the observed range.

Further increases in yield would certainly be possible if intense fishing were continued after the fish leave the East Pacific. Estimates of the potential total yield of 225,000 tons, and 140,000-1.19 million tons have been made by Silliman (1966) and Rothschild (1965) respectively. Rothschild's higher figure is based on a very short stay (2 months) in the East Pacific, and is almost certainly too high.

Pooling all the estimates suggests a figure of around a quarter of a million tons as the total potential of the skipjack which pass through the East Pacific fishery. To this might be added an equal amount for the fish spending their juvenile life in the West Pacific.

This estimate, of around half a million tons, is of average annual catches. Skipjack catches fluctuate greatly, and it is not certain to what extent this is due to real changes in stock abundance (e.g. due to changing year-class strength) and how much to changes in availability - the fish not moving into the fishing area, or moving in, but behaving abnormally. These fluctuations and an understanding of their causes are important for the commercial possibilities of further development of the skipjack resources.

4.6 Bonito

The only other tunas (in the wider sense) at present fished in quantity are bonito (*Sarda* spp.). Though the fish are widespread, specialised bonito fishing is restricted to a few areas - Peru and the Mediterranean; fair quantities are also taken around Japan and also substantial quantities (estimated as up to 30,000 tons) (Clarke and Sosin 1969) by sports fishermen on the US west coast and smaller amounts in other areas (Demir 1963, Kikawa *et al.* 1963). No full assessment has been made for any of these stocks. The fisheries are carried out by a variety of rather primitive gears (trap nets, beach seines, trammel nets, etc.), so it is probable that some expansion of catches is possible even in the heavily fished area.

4.7 Other Fish

Some other species, such as squids and saury, occur widely over the open ocean, and are also caught in quantities. The present fisheries (e.g. off Japan) are however carried on in coastal, and near-coastal waters, and are discussed in the appropriate area chapters.

5. OTHER ESTIMATES OF POTENTIAL

5.1 Eggs and larvae: tunas

The information on the distribution of eggs and larval tuna has been summarised by Yabe *et al.* (1963), for the Pacific by Matsumoto (1966), and for the Atlantic by Richards (1969). Problems of identification obscure any clear picture of the distribution of albacore larvae, though they probably lie outside the central equatorial band, in which oceanic sampling has been most intense. Larvae of bluefin and bigeye tuna are rather scarce, but for other species the distribution is quite clear.

Two species, skipjack and yellowfin, have wide trans-oceanic distribution of larvae within the tropics with, in the Pacific, centres of abundance in the coast around the Philippines, and in the centre round Hawaii. There is also an eastern centre of yellowfin larvae along the American coast.

Of the smaller tunas, little tuna and bonito are common near the continental coasts, including inside the Mediterranean, but are not found in mid-ocean. Frigate mackerel are widely distributed and in some areas are the commonest larval scombroid.

Except off Central America skipjack larvae are more abundant than yellowfin. The graphs of Matsumoto (1966) suggest ratios of from 2:1 to 8:1 in the Central Pacific. Matsumoto (1958) found 59% skipjack and 22% yellowfin (plus 1% frigate mackerel, and other unidentified tuna larvae) south of Hawaii. Nakamura and Matsumoto (1965) found 64-83% skipjack, 3-11% yellowfin, 6-7% bigeye and 2-14% frigate mackerel round the Marquesas. Ueyanagi (personal communication) found a ratio of 6:1 of skipjack to yellowfin in larval catches in the Atlantic.

Total catches of the three main species in the EQUALANT surveys were 403 skipjack, 367 yellowfin and 98 bigeye, i.e. relatively fewer skipjack than found by Ueyanagi.

Since the fecundity (in terms of numbers of eggs per kg) and the early life history - growth and mortality of larvae - probably does not differ too much between species, the ratio of biomass of adult females and probably also the ratio of potential yeilds, may, as a first approximation, so be taken as similar to the ratio of larval abundance set out above. This would suggest rough estimates of skipjack potential about 4 times that of yellowfin i.e. 600,000 tons in the Pacific, 160,000 in the Indian Ocean, and 250,000 in the Atlantic. These figures are similar but rather lower to those estimated by Ueyanagi, based on larval data and frequency of juveniles in billfish stomachs - (quoted by Kikawa *et al.* 1969) - 800,000-1 million in the Pacific, and perhaps 300-400,000 tons in the Indian Ocean. The Pacific figure is in at least as good agreement as can be expected with the estimate of 500 000 tons obtained earlier by rough stock assessment methods. Since the yellowfin spawning stock has presumably been relatively further reduced by fishing than the skipjack, the latter figure may be the better estimate.

The coastal distribution of tuna larvae for the East Pacific has been given by Klawe (1963). The distribution of yellowfin and frigate mackerel is similar, the latter being about three times as abundant. Black skipjack or little tuna (*Euthynnus lineatus*) are more southerly; off Costa Rica they were about as common as yellowfin. The data suggeststhat the frigate mackerel is an important resource in the area; if it is assumed that the yellowfin larvae represent the complete production from the yellowfin fished in the East Pacific, then a rough estimate of the frigate mackerel potential could be, assuming the same larval production per unit adult biomass for the two species, 3 x 70,000 = ca 200,000 tons; because not all the yellowfin may spawn in the area, and also the spawning stock of yellowfin has been reduced by fishing, this figure is likely to be an upper limit.

Other information from the EASTROPAC and EQUALANT studies, and in the Indian Ocean suggest that the frigate mackerel is widely distributed in all oceans, and may be the most abundant oceanic scombroid. If so its potential could be of the order of 1 million tons.

6. OTHER RESOURCES

6.1 Sharks

These are common in all the oceans (Strasburg 1959). Quantities of large shark are taken on the tuna long-line fishing, and 7,000 tons, mainly of great blue shark, are landed in Japan. It seems likely that immediate catches could be increased substantially by fishing specifically for sharks. However, the present longline fishing is probably quite efficient for catching sharks. Also, presumably because of their low fecundity, elasmobranchs seem able to sustain only a low fishing rate - for example the British Columbia dogfish stock declined very rapidly when being fished for livers, and more recently the Norwegian shark fishery in the northwest Atlantic (the only specialised oceanic shark fishery), mainly for porbeagle, expanded rapidly to 8,000 tons in 1964, but thereafter declined to 1,400 tons in 1966.

Excluding coastal stocks of small sharks and dogfish, the potential of large oceanic sharks may be no more than a few hundreds of thousands of tons, if as much.

6.2 Other medium to large surface fish

Dolphin fish (Coryphaena spp.) are widely distributed in the warmer seas, both in coastal waters, and in the open ocean (Gibbs and Collette 1959, Rothschild and Uchida 1968). Because it congregates near floating objects and is a popular sport fish, it is conspicuous, and therefore its absolute abundance may not be exceptionally high. For instance, in the extensive collection of small fish in ring trawl and Isaacs-Kidd trawl reported by King and Iversen (1962) only one coryphaenid was found (compared with 6 juvenile tunas) and coryphaenids comprised only 1 ml of micronekton in samples reported by Blackburn 1968, Thunnidae 2 ml. Possibly the potential is of the same order as that of tunas, of the order of 1 million tons, and perhaps rather less.

Pomfret (Brama japonica) have been reported over a wide area of the North Pacific during exploratory fishing for salmon (Larkins 1964, Hitz and French 1965); no other species, apart from salmon, was found in numbers in the open ocean. The potential of pomfret may be large, and similar resources may exist in other oceans.

Saury (Cololabis saira) are also found widely over the temperate oceans, though the centres of distribution are close to the continental shelves. In some of these latter areas (e.g. off Japan) they are heavily exploited. The relation between these fish and the oceanic stocks is not known, but they may, in each ocean, form parts of the same stock. The potential of the shelf stocks are discussed in the appropriate section. There may be additional potential from the fish in the open ocean, but lacking data on the population structure, no attempt will be made to estimate it.

6.3 Small pelagic animals

There is no doubt that the potential resources of small animals, some of them the food of tunas, in the open oceans is very large. The abundance of smaller organisms is well demonstrated by the existence of the Deep Scattering Layer, which is such a prominent feature of echo sounder records in many parts of the ocean.

Systematic observations of the groups of animals (1-10 cm long, the micronekton of Blackburn (1968) are few being mainly in the East Pacific (e.g. King and Iversen 1962, Avon 1962, Berry and Perkins 1966, Voss 1967). These show that, as might be expected, the density is variable, and corresponds reasonably well with the distribution of nutrients, primary production, and zooplankton, but that even in the poorer areas appreciable catches (in terms of biological samples) can be taken with appropriate gear.

Detailed examination of the catches show that many families common in net samples occur rarely in tuna stomachs and vice versa. The nets used do not seem to catch the most active animals (including small tuna) while the large tuna do not eat the deeper living animals which only come to the surface at night.

Some of the common group of fishes found include Myctophids, Paralepids, _Cyclothone_ spp. (especially in deeper hauls), Gempylidae, _Vinciguerra_ spp., and Leptocephalae. Among crustaceans the dividing line between larger zooplankton, and the smaller nekton is rather subjective. Blackburn included adult euphausids among micronekton, in which they were common, as were stomopods, portunids and galatheids. Most of these are widely distributed, being commonest in the more productive areas (e.g. Gulf of Guinea, Peru Current, etc.), but occurring elsewhere. The outstanding exception is the red crab (_Pleuroncodes planipas_), which is exceedingly abundant off Baja California (Longhurst 1967, 1969) but rare elsewhere.

Except for the red crab the immediate likelihood of exploitation of these animals is low. The market for such small and generally unattractive animals would be for fish meal, and therefore very large catches would be required. Though the total potential harvest is undoubtedly large - of the order of hundreds of millions of tons - there are no data yet on the aggregation of animals or on the design of suitable gears, to suggest the possibility in the near future of getting the sizes of catches required - around 10 tons/day for a 50-70 ft vessel, or greater for larger and more expensive vessels.

As Longhurst (1967) points out the possibilities for red crab are much better. The animal is similar to galatheid crabs already being harvested in Chile, and could be used for human consumption at a reasonable price, and very large concentrations are found. The crabs exist in both a pelagic and benthic phase, the interaction between which is not fully understood. In the crustacean chapter of this report a conservative estimate of the potential harvest of 25,000 tons is given, based largely on extrapolation from the bottom trawl fishery for similar species in Chile. This figure may be taken as estimating the potential from its benthic phase, feeding on the limited production of the narrow continental shelf. The potential from the pelagic phase is very much greater. Some rough measure of this is given by the figures of standing crops, from Blackburn (1968). In his area 01, which measures around 300 km wide by 1,800 km long (ca 500,000 km^2), catches of _Pleuroncodes_ were around 100/1,000 m^3 of water sampled. If this represents the population down to 100 m, it is equivalent to a density of 10 g/m^2, or a total standing crop of 5 million tons. With a life-span of 2 years, the annual production might be half this, and the possible harvest about 1 million tons. These are only rough calculations of the order of magnitude. Also there are large year-to-year changes in the distribution and abundance, e.g. a large northward extension in 1958-60.

6.4 Squids

These occur in all oceans, and are generally believed to form a major unexploited resource. Presently exploitation is limited to a few of the coastal and offshore stocks, particularly off Japan, as discussed in the regional sections. The general biology and systematics of squid have been recently reviewed by Clarke (1966). This review shows clearly how little quantitative or even approximately quantitative information is available concerning the squids of the open ocean. Among the stocks along the continental shelves discussed in the appropriate regional sections there is a reasonable estimate (around half a million tons) of the potential of the common squid (_Todarodes pacificus_) of the Northwest Pacific. The rougher estimates obtained on the relevant sections for the other coastal stocks - off Newfoundland, Northwest Africa etc. are probably within an order of magnitude. The open ocean resources are probably less abundant per unit area than these except perhaps along the equatorial upwelling zone, but extend over a much wider area. Their total magnitude is therefore probably greater than the shelf resources - perhaps a few million tons, but not so much as 100 million tons. The possibility of exploiting these oceanic squids has been discussed by several authors, including Clarke (1966), Voss (1967) and Idyll (1968). Commonly used squid gear, such as the jigger, would seem usable, though would depend on suitable aggregation of animals. It does not seem to require too much of an advance in terms of value of the fish, fishing techniques or ability to locate favourable areas, for exploitation of oceanic squids to be economically feasible, and at least the prospects are more favourable than for the smaller oceanic fish.

6.5 Comparison with primary and secondary production

The use of information on primary or secondary production is made difficult and inaccurate because of uncertainties about the efficiency of transfer from one trophic level to the next, and of the precise position of the potential resources in the food web. These uncertainties are well illustrated by the table prepared by Schaefer (1965). Here there is enough information at least for the Pacific for the data on basic production to be used to give rough confirmation of the estimates in earlier sections.

Using alternative factors of 10% and 20% for the carnivorous stages, and a round figure of 7 x 10^9 tons of herbivorous zooplankton, the estimates of annual production in the Pacific (in terms of wet weight, except for primary production), are, from production data, in millions of tons:

Plants	6.4 x 10^3C
Herbivores	5-10 x 10^3, say 7 x 10^3
First stage carnivores	700-1,400
Second stage carnivores	70-280
Third stage carnivores	7-56

while rough estimates of potential of fish and other animals are, taking the Pacific as half the total:

Tunas	say 1.5
Other large fish (sharks, coryphaenids, etc.)	1
Squids	5-50
Myctophids, etc.	hundreds

The latter figures would seem to be reasonable if, as is not unlikely, myctophids, etc., are first or second stage carnivores, squids are second stage carnivores, and tuna and other large fish are third stage carnivores.

7. DISCUSSION AND REQUIREMENTS FOR FURTHER RESEARCH

The rough estimates for these resources may be summarised as follows:*

Table P4 - Summary of potential catches from oceanic resources (tons)

Whales, etc.	Large baleen: 1,900 BWU =		1,640,000
	Sperm whales: 25,000 animals =		500,000
	Small whales		500,000
	Dolphins, porpoises		?
Salmon		North Pacific	500,000
		Atlantic	15,000
Tunas	Large tunas:	Pacific	350-450,000
		Atlantic	200-250,000
		Indian Ocean	100-150,000
	Skipjack	Pacific	500-800,000
		Atlantic	250-300,000
		Indian Ocean	160-300,000
	Other small tunas:	Frigate mackerel	(1,000,000)
		Bonito	(500,000)
		Little tuna	?
		Thynnus tonggol	?
Sharks			(500,000)
Coryphaenids			(1,000,000)
Squids			10-100 million
Myctophids, etc.			hundreds of millions
Red crab			(1,000,000)

Note - Salmon are included here because most of their growth is put on in the open oceans, though their potential is discussed in detail elsewhere

The oceanic resources fall, in relation to exploitation, into two classes - the whales, salmon and larger tunas, which are mainly fully or over-exploited, and the other resources which are virtually untouched.

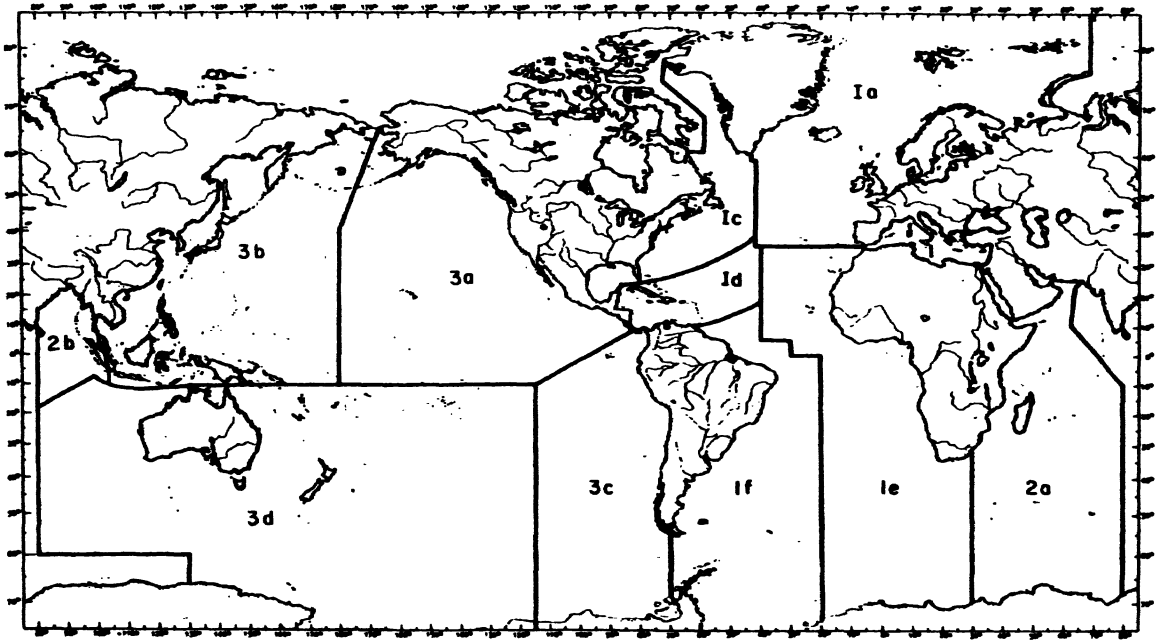
The requirements for the two groups are naturally very different.

For the exploited group the needs are mainly for better data for management - and also better and more effective machinery for implementing management. Statistics are as usual a basic requirement: on the whole these are satisfactory, but better data are required for some tuna fisheries, especially on the area of capture. More extensive data on sizes of fish caught are needed for nearly all tuna fisheries. This is particularly important in view of the different sizes taken by different gears.

Better information on population structure (possible stock separation) is required for the several fisheries where exploitation is far from being uniform over the whole range of the species. This is particularly required for sperm whales, yellowfin tuna, and skipjack tuna in the Pacific. Some other requirements for tuna including the need for basic research on the relation between stock and recruitment are discussed in the report of the Miami meeting (FAO 1968).

For the smaller tuna, including skipjack in most areas, and also surface schools of medium size full of the larger fish, e.g. yellowfin in the northwestern Indian Ocean, substantial improvement to estimates of potential will mainly come only after exploitation has increased. There is enough information to show that the potential exists, and the immediate research need is for information that will assist the development of exploitation.

For the other 'unconventional' resources, the estimates are extremely rough. However, for practical purposes these are probably sufficiently accurate to show that if the problem of harvesting could be solved, the potential is extremely large. There is, therefore, no immediate urgency to improve the estimates, but rather to undertake research to make harvesting more possible. This will include technological research on catching and processing methods, as well as research on the distribution and behaviour, especially occurrence of concentration of the organisms concerned.



Q - REGIONS OF THE WORLD USED FOR STUDYING MOLLUSCAN RESOURCES

INTRODUCTION

The commercial and potentially commercial species of mollusc include active mobile carnivores, less mobile herbivores and stationary or almost stationary filter feeders. This variety of behaviour determines to a considerable extent the means by which the maximum production can be achieved. With some species rational exploitation of naturally reproducing stocks, similar to exploitation of most fish stocks, is the only way to obtain maximum yields, while with others varying degrees of cultivation have been practiced for centuries and can be further developed to provide very substantial increases in yield.

Mobile carnivores

The mobile carnivores are all gastropods and include many large marine snails such as the whelks that feed on living bivalves and will eat dead flesh of many types of animals. They are often very abundant and can be important competitors with fish for the same food. Their greater exploitation would be generally advantageous to fisheries.

Some of these species have rather tough meats and the markets for them are at present limited; however, a number of other species are very highly prized. More intense exploitation of these gastropods is likely to be very generally possible and maximum yields will depend on the usual factors controlling the population dynamics of exploited natural populations, the growth, mortality and reproduction.

Mobile herbivores

These molluscs are also all gastropods and include the winkles, limpets, abalones (ormers) and conchs. They browse on bottom living algae and therefore are all limited to the photic zone and some of them are predominantly intertidal.

All winkles and most limpets are small and winkles are difficult to extract from their shells. Neither group is likely to be of much commercial importance. However, the conchs of the Caribbean are large herbivores which are common on soft grounds and have played an important role as a staple supply of protein in the area. Abalones can also be quite common and large, but living on a rocky coast, can only be harvested by diving and removal from the rocks one at a time by hand which makes large scale mechanical harvesting impossible. The maximum yields of both groups at present depend on rational exploitation, though in Japan the artificial rearing of abalones is being developed.

Filter feeders

This group of molluscs, which includes all bivalves, is of great importance to food production as they all feed on diatoms, flagellates and bacteria and thus make direct use of the primary production.

The extent to which cultivation has so far contributed to increasing production and the methods used in cultivation depend largely on the mobility of each species and their form of attachment, if any, to the substrate.

(a) Scallops

Of the commercially useful filter feeders the scallops are the most mobile, being capable of swimming short distances in escaping from predators and reacting to the nature of the substrate. This degree of movement is likely to make farming them more difficult than with more sedentary species, although artificial rearing has been achieved in Japan.

At present maximum yields from natural stocks depend on rational exploitation.

(b) Clams, Cockles, Arc Shells

Practically all clams, cockles and arc shells live in the bottom sediments either just covered by them or buried up to a depth of several times the length of the shell. Some species attach themselves temporarily to the stones on the bottom by bysses threads which can be detached at will, but most are not attached in any way and have little power of movement except to dig themselves into the sediment.

It is characteristic of most molluscs, including the clams, that settlement of the young spat following the planktonic larval stages is very variable from year to year, both in abundance and in location. Being incapable of much or any lateral movement this frequently leads to the settlements being locally very dense and not always in the areas where good growth will subsequently occur. The density of settlement often leads to intra-specific competition and reduced growth.

In some countries, and particularly Japan, the gathering of young spat of several species of clams from areas of dense settlement and their replanting on private grounds has become standard practice. Maximum yields from these natural stocks will, therefore, be achieved by a combination of transplantation to good growing grounds, and the use of sound cultivation methods, including predator control. Artificial rearing of a variety of clams has proved relatively simple and can be expected to play an increasing role in developing production among the more highly priced species.

(c) Mussels

The characteristic feature of mussels is that they do not bury themselves but attach themselves by temporary byssus threads to a hard substrate which may be rocks, other shells including mussels, mangrove haustoria or man-made materials.

Being thin shelled, young mussels are an important food of many fish, crabs and starfish and therefore some species rarely survive to a commercial size below low water mark. However, they are often very abundant and survive in very large numbers intertidally where predation is reduced but where due to exposure they do not grow so well or fatten so well as at lower levels.

Various forms of cultivation have been used to increase production and/or increase the quality of the product. These include a relaying of mussels from demersal settlements or of intertidal slow growing mussels to private grounds where they will grow and fatten well and where some predator control can be included. The methods that have been developed for this type of cultivation are amenable to large scale mechanisation as in Holland and the UK.

In France the enormous abundance of mussel spat in the plankton has been the basis of obtaining stocks by providing wooden posts in suitable localities to receive the spat. The young mussels are subsequently transferred to fences (bouchots) where they grow and fatten well.

More recently the habit of the mussel to attach itself to a substrate has been used in the development of hanging culture in which the spat is caught on ropes suspended from rafts and subsequently transferred to other ropes at a lower density for growing on. Mussels gathered from wild stocks may also be used for hanging culture. In this way a very high production below unit area of surface can be obtained in suitable areas.

Good mussel grounds can carry up to 150 tons whole mussels per hectare grown on the bottom, while in hanging culture one raft can carry 50-60 tons of mussels. The actual size of the raft may be 18 m x 18 m, but there have to be sufficient spaces between the rafts so that the harvest from one raft effectively comes from an area of 100 m x 100 m.

(d) Oysters

The features of oysters that have made them so widely gathered and cultivated are their abundance in inshore waters, great tolerance of varied environmental conditions, capacity to remain alive out of water for long periods simplifying transplanting and marketing and their popularity as food. On the other hand, no other commercial mollusc appears to be so much affected by diseases which have from time to time caused major mortalities, though these may be due more to a history of monoculture than to a basic susceptibility of oysters.

The production of seed oysters has largely been by providing suitable surfaces for settlement at the best times and places. Mussel shell, limed tiles, mangrove sticks, bamboo sticks and strings of oyster shells have all proved successful with different species or under different conditions. Typically the seed is laid on the bed of the estuary or other sheltered water, but more recently hanging culture, which gives faster growth than for oysters laid on the bottom, is proving very successful for several species. The production of large quantities of seed oysters in a prolific spatting area permits the seeding of ground with less regular production and also grounds which, while not normally producing oysters, are very good for growth and fattening.

Oyster grounds can carry over ½ million adult oysters per hectare with an annual production of around 50 tons whole oysters or 8 tons meat per hectare.

AREA REVIEWS

The landings shown in this section are derived from FAO published statistics for 1966 (FAO 1967), unless otherwise stated. More up to date and detailed statistics are given in Appendix Table Q1. Where additional data on landings are derived from national statistics or scientific reports, these sources are stated. Some countries do not provide returns for molluscs and some returns are not broken down to species or groups of species. Also considerable quantities of molluscs are gathered by individuals for their own use or sold at local coastal markets without any records of landings being kept. For this reason the available statistics of mollusc production are undoubtedly under-estimates in most cases and considerable under-estimates in others.

The text of this chapter should be read in conjunction with Appendix Table Q1 which sets out the landings for 1958/68 for each mollusc group by countries and geographic areas. The regions used differ slightly from those used in the detailed regional reviews and are shown in Figure Q1.

A. ATLANTIC

Region I - Northeast Atlantic: total production 368,000 tons

Scallops: 10,900 tons

Pecten maximus: 8,200 tons - France, UK, Eire, Spain

Chlamys varia:
2,700 tons - France, Spain
Chlamys opercularis:

Pecten maximus is one of the largest scallops of the world and produces excellent meats, which are highly prized. In the past it has been sold largely alive but, as it does not live long out of the water, the market prepared to take this very perishable product was limited. However, now that an increasing proportion of the catch is being frozen the market has expanded and is capable of absorbing all the scallops that can be landed.

There are probably some stocks in the eastern North Sea and round Scotland which are not yet exploited but the major stocks in the Irish Sea and in the English Channel and down to Spain are well known and heavily exploited. Some increased catch would come from greater exploitation of the few lightly fished stocks and a little from more rational fishing of the heavily fished ones, but it is unlikely that yields from the Northeast Atlantic could be increased beyond about 15,000 tons.

The smaller queen scallops, *Chlamys varia* and *C. opercularis*, are locally very abundant from Norway to Spain. They are very good food, but do not travel well alive, are costly to schuck and only in France form important fisheries.

Equipment is being developed in Florida, USA, for shucking small scallops and if the costs of shucking can be overcome the production of these small scallops could increase substantially, probably to more than 20,000 tons.

Clams, Cockles: 59,600 tons

Cockles: *Cardium edule*: 36,100 tons - Spain, UK, France, Holland, Portugal

Hard clams: *Venerupis decussata*:)
) 5,300 tons - Spain, Portugal, France
Venerupis pullastra:)

Venus verrucosa:)
) 18,100 tons - Spain, France
Venus gallina:)

Razor clam: *Solen* sp.: 100 tons - Spain

Little is known about the stocks of any of these species, most of which are intertidal and are exploited by digging and raking. It is probable that some of these species are also present in considerable numbers below low water mark.

In Holland cockles have been harvested for several years with a hydraulic dredge which is used over the high tide period and which washes the cockles out of the sand by a series of jets of water playing onto the bottom in front of the dredge. Recently (UK, White Fish Authority 1967) a modification of this dredge has been developed which brings the catch to the ship by a pipe, allowing continuous fishing in water down to about 20 ft (6 m). This dredge should substantially reduce costs, permit fishing on stocks of lower densities and below low water mark and possibly bring into use offshore species such as *Mactra stultorum* which has not as yet been used for human food because of the difficulty of harvesting.

The more full utilization of existing stocks by all countries at present harvesting them could probably raise yields to around the 100,000 tons level.

In addition, the artificial rearing of the American hard clam *Mercenaria* is now well advanced in the UK and France and should be adding substantially to national production by 1975. The artificial rearing of *Venerupis* (*Tapes*) spp. is also proving simple, though the protection of clams from crabs (*Carcinus maenas*) while small is an important problem if layed in the sea too soon.

Mussels: 222,400 tons

Mytilus edulis:	all countries Denmark to Spain
Mytilus galloprovincialis:	

These two species overlap in distribution; *M. edulis* is the northern form and is present throughout the area while *M. galloprovincialis* is common in the south and does not extend north of about 52°N.

Mussels are one of the commonest molluscs in coastal water of the Northeast Atlantic and the young occur abundantly from about half-tide level to depths reaching some 30 m. There is very heavy natural predation by fish and invertebrates resulting in consumption size mussels (over about 5 cm length) being found chiefly intertidally where they escape predation. However, at high levels exposure for long periods results in poor growth and poor meat conditions (Baird 1966).

Harvesting by hand with simple tools has been the standard method of collection for many centuries. One method of simple culture used in the UK and elsewhere has involved transferring slow growing poor mussels from high intertidal levels to about low water mark where they grow well and fatten and are harvested by hand or with long-handled rakes from small boats. Cultivation in Holland and more recently in the UK, has been based on trasferring small seed mussels from natural settlements below low tide level to private lays in shallow water at or a little below low water of spring tides (Lambert 1935, 1951). The mussels are gathered by dredging into boats that can carry up to 50 tons at a time. A similar harvesting by dredging occurs on the rich natural beds of mussels in the Limfjord of Denmark.

The pattern of production of mussels in Holland is changing due to the closure of the large shellfish producing areas in the south for coastal protection reasons and the intensification of production in the Waddensee in the north of Holland. Verwey (1952) has shown that the Waddensee acts as an accumulating basin of nutrient materials and therefore has a great productivity. Havinga (1956) estimated that the mussel production in the Waddensee could reach about 100,000 tons, which would mean that Dutch production of mussels could be slightly increased in spite of the loss of the southern Delta region. New assessments of potential maximum mussel production are currently being made which may modify Havinga's estimate.

On the Atlantic coast of France mussels are cultivated by two methods. Some are relaid on the flat, but the majority are now cultivated by the bouchot method. In this method spat is collected from large numbers of vertical posts driven into the sediments a little below low tide level. Shoreward of the posts are placed fences made of branches woven horizontally between vertical posts and onto these are placed the spat which remain on the fences until ready for harvest. Vast areas are devoted to this method at St. Malo, Vannes and La Rochelle. There are many areas on the west and north costs of France suitable for cultivation on the flat and on bouchots and conditions might also allow for some hanging (raft) culture such that mussel production could probably double, to around 70,000 tons, but this is likely to depend on sociological conditions as the current bouchot culture requires considerable labour.

Experiments in the growing of mussels from rafts started in Galicia (Spain) in 1946; production reached 10,000 tons by 1956 and was 130,000 tons in 1967 (Andreu personal communication), though official statistics give a lower figure. In this method ropes are suspended from outriggers from an old boat or a specially constructed raft and yields of some 50-60 tons are obtained in a year from a raft 18 m x 18 m. In Spain the suitable sheltered areas for hanging culture are limited, but Andreu (1968) considers that with full utilization of the suitable sheltered areas and some reduction in the distance between the rafts, production might be about doubled, to 250,000 tons, over a number of years. The most probable obstacle to this increase is considered to be inadequate consumer demand.

Vilela (1967) considers that there is scope for some expansion of mussel production in the R. Mia area of Portugal.

In Scotland and Norway there is considerable interest in raft culture and current experiments are encouraging though the low temperatures are likely to mean that the mussels take about twice as long to reach commercial size as in Spain. In England and Wales the strong tides and the scarcity of well sheltered estuaries are likely to preclude raft culture on any appreciable scale. There would, however, appear to be considerable scope for the expansion of mussel culture on the bottom by using mechanised techniques in the UK, Eire and probably the German Waddensee (Meyer-Waarden 1968), which could increase production from the present 10,000 tons to at least 50,000 tons for the three countries.

It would seem practicable for mussel production in the Northeast Atlantic area to increase by 50% in the next decade but would have difficulty in doubling, though suitable areas for greater production are present.

Oysters: 64,400 tons

Flat oyster: *Ostrea edulis*: about 7,000 tons - France, UK, Eire, Spain, Netherlands

Portuguese oyster: *Crassostrea angulata*: about 57,000 tons - France, UK, Spain, Portugal

Oyster production in Europe goes back 2,000 years, the maximum production probably occurring during the latter decades of the nineteenth century following which there has been a substantial decline in some countries, especially in higher latitudes where *Ostrea edulis* (the European flat oyster) was the main species grown. While this oyster was a cheap abundant food 100 years ago it now has a very high sale value.

Production of *O. edulis* has been reduced by pollution, disease and introduced competitors. There has always been a tradition of imported seed oysters from the more southern parts of Europe where spatfall is more regular and abundant to the north, but now the supply of *O. edulis* from the southwest of France and *C. angulata* from Portugal and the Gironde estuary in France is far from adequate to meet the needs of the more northerly countries. Even France cannot always obtain enough spat of both species for her own needs. It is probable, however, that improved methods of spat collection in reliable spatting areas of France would permit a substantial increase in the production of consumption oysters by France and elsewhere. In the UK although production is now very low there are many productive estuaries which could yield more than the past peak production of 8,000 tons if seed were available.

Current research in the artificial rearing of oyster spat is proceeding in the UK (Walne 1966) and France, and if successful, could lead to abundant seed of *O. edulis*. Experiments are also being done in the UK on the rearing of the Japanese oyster (*C. gigas*) and the New Zealand oyster (*O. lutaria*) because of the fast growth of the former and the short planktonic life of a few hours of the larvae of the latter. Both species could lead to a further increased production. One of the advantages of growing both *O. edulis* and *C. angulata* or *C. gigas* in cooler waters is that the latter do not spawn species but have large gonads and are in a very good condition for harvesting during the summer months when *O. edulis* is in poor condition and unsaleable.

Given an adequate supply of seed it is probable that French production could reach 20,000 tons of *O. edulis* and 100,000 tons of *C. angulata* and the production of the UK, Belgium, Holland, Germany and Denmark could together reach 20,000 tons. Portugal produces only some 500 tons of oysters for consumption but supplies very large quantities of seed oysters for the rest of Europe. It has few areas suitable for fattening and production of consumption oysters is not likely to increase much. In Spain some 600 tons of flat oysters and 1,000 tons of Portuguese are produced from natural banks, but hanging culture in which flat oysters are attached by cement to cords of nylon suspended from rafts has recently started (Andreu 1968) and can be expected to add substantially to this production of this species. However, while an increase in oyster culture in the place of mussel culture might produce a more valuable crop, the amount of protein produced is likely to be substantially less.

Gastropods: 4,600 tons

Winkle: *Littorina* spp.: 2,700 tons - Eire, UK, Spain, Holland

Whelk: *Buccinum undatum*: 1,900 tons - UK, Holland Belgium

Ormer or abalone: *Haliotis tubercularis*: small quantities - Spain, France

Although winkles are generally common along most coasts of the area the yield of meat is very small and difficult to extract. It seems unlikely that the production will increase much.

The whelk is an extremely common northern carnivorous species which is caught in baited traps round England (Hancock 1967) and by dredges in Holland. The flesh is very firm and not particularly attractive. There is no doubt that the stocks round Britain, and in the North Sea generally, could yield at least tens of thousands of tons if the demand was created.

The ormer (*Haliotis tubercularis*) is a southern species, the northern limit of which is the French side of the English Channel as far as and including the Channel Islands. There are small fisheries in Spain, France and the Channel Islands but this species is relatively small, rarely exceeding 12 cm long and never very abundant. It is unlikely to prove sufficiently common anywhere to give appreciable yields.

Region II - Mediterranean and Black Sea: reported production 30,700 tons

Official statistics of landings of molluscs from this area are rather incomplete and where given (Italy and Greece) are not broken down fully into species. Most mollusc species found in the Northeast Atlantic area are also present in this area.

Scallops

Pecten maximus and *Chlamys* spp. are recorded from France, Italy, Greece and Algeria (Gruvel 1926) but recorded landings are under 10 tons. These species do not appear to be abundant or capable of supporting a substantial fishery.

Clams, Cockles and Arc Shells

Cardium edule, *Venerupis* spp., *Solen* spp., *Arca noe* and *Tellina* sp. are all common in the Mediterranean and many species are gathered and used on a substantial scale, especially in Italy and in France, but few details are available. France records 110 tons of palourde (*Venerupis* spp.) from the Sète area (France 1967) and 920 tons of "various molluscs" which are probably largely clams Similarly, Italy records 8,200 tons of various molluscs other than mussels, and here again a large proportion is almost certainly clams. Although cockles are common and known to be abundant in Greece (FAO mimeo report) they appear to be little used. Present production would be at least 10,000 tons and could probably be doubled. There are indications that production could be increased several-fold.

Mussels: 19,870 tons

Mytilus galloprovincialis: Italy, France, USSR

Mussels are present throughout the Mediterranean, and are cultivated on a large scale at several places on the east and west coasts of Italy (including Taranto and Salerno) and at Sète in France. At Taranto, cultivation is done on reed cords suspended from ropes held horizontally between tripods or between floats (Parenzan 1958), and recorded production is in excess of 7,500 tons annually and probably substantially more. In the vicinity of Sète the mussels are cultivated both by the standard French bouchot method and on tarred ropes suspended from horizontal poles supported at intervals by vertical posts. In 1966 7,600 tons were produced in this area using these methods.

There are many sheltered parts of the coast of Yugoslavia and FAO/UN (1961) has reported that conditions are suitable for mussel culture similar in form to that used in Italy in some twelve localities along the coast. No doubt suitable sites would also be present round Greece and other parts of the Mediterranean and Black Sea.

It is probable therefore that hydrobiological conditions exist for mussel production in this region to be increased at least beyond the 50,000 ton level without many problems.

Oysters: 720 tons

Ostrea edulis: France, Italy, Yugoslavia

Crassostrea angulata: France, Italy

Ostrea taurica: USSR

The flat oyster O. edulis is widespread in the area but it is not the basis of a large fishery anywhere and appears not to fatten as well as on the Atlantic coast. Cultivation of the Portuguese oyster (C. angulata) is largely limited to France and the North African coasts of Algeria and Tunisia and does not reproduce readily under the conditions generally present in the estuaries of the Mediterranean(FAO/UN 1961). Small quantities (20 tons) of O. taurica are landed by the USSR.

FAO/UN (1961) has reported favourably on the possibility of introducing hanging culture of O. edulis on the coast of Yugoslavia and progress is being made on an experimental basis (Nikolic and Stojnic 1962).

Vardaro (1955) considered that oyster production in Taranto, Italy, could be increased again to give an annual output of 10 to 15 million oysters or about 500 tons.

Azous (1966) suggests that the cultivation of O. edulis is not likely to be successful on the Tunisian coast due to too high spring temperatures, but considered that C. angulata would grow well in Bizerte where a substantial culture could be developed, though it may prove necessary to rely on seed oysters from other areas.

Thus there appear to be considerable problems in achieving a substantial oyster production. General low productivity of Mediterranean waters may preclude the large scale cultivation of good quality oysters and other bivalve molluscs from many areas. C. angulata may be more successful in the long run if an area can be found which will give large scale reliable spatfall and which can be used as the area for supplying seed for growing on elsewhere.

Gastropods

Small numbers of gastropods are gathered but no landings data are available.

Region III - Northwest and Western Central Atlantic: reported production 640,000 tons - Canada, USA

Scallops: 146,000 tons

Sea scallop:	Placopecten magellanicus: 128,000 tons - Canada, USA
Bay scallop:	Aequipecten irradians: 7,400 tons - USA
Iceland scallop:	Chlamys islandicus: small quantities
Calico scallop:	Pecten gibbus: 10,500 tons - USA

The main fishery for scallops is for the sea scallop the distribution of which is from Cape Hatteras (36°N) to Newfoundland (50°N) and forms a major resource on Georges Bank which is exploited by boats of 65 to 95 ft (21-31 m) from the USA and Canada working in 40 to 80 m water using 12 ft (4 m) wide dredges. More limited concentrations are worked by Canadian boats along the Canadian coast and by US boats between Cape Cod and the mouth of Chesapeake Bay (Bourne 1964, Merrill 1960).

The recent development of the fishery has been the increased fishing of Canadian boats on Georges Bank. This fishery is being studied closely to determine the best means of management. Preliminary assessments suggest that the Georges Bank stock could stand limited further fishing and the more northerly and southerly concentrations could yield increased catches. Landings of sea scallops may in fact be above those shown at the head of this chapter as the ICNAF Statistical Bulletin records 117,000 tons in 1964. Potential yields from this species are probably around or a little above 150,000 tons in live weight annually. The yield of usable product could be further increased by at least 10% if the gonads were utilised when well developed as is the case with Pecten maximus in Europe.

The bay scallop is caught from New England to the Gulf of Mexico with a yield of 1,887,000 lb meat (6,700 tons live weight) in 1964 (US Fish.Stats). Production could probably be increased to about 10,000 tons.

Clams: 188,800 tons

Hard clam: *Mercenaria mercenaria*:)
) 51,200 tons - USA
Mercenaria campechiensis:)

Soft clam: *Mya arenaria*: 28,900 tons - USA, Canada

Surf or
Bar clam: *Spisula solidissima*: 108,100 tons - USA

Ocean quahog: *Arctica islandica*: 300 tons - USA

Ensis sp.: small quantities

Rangia clam: *Rangia* sp.: 200 tons - USA

At least six species of clam are exploited commercially along this coastline, of which the hard clams, soft clams and surf clams account for over 90% of current production.

The hard clams are two closely similar species of *Mercenaria* (previously *Venus*) of which *M. mercenaria* is the more northern, is heavily exploited and makes up the majority of the total present landings. The more southern species *M. campechiensis* extends from Chesapeake Bay to the Caribbean with the main grounds off N. Carolina (Porter and Chestnut 1962). It was more heavily exploited off Florida in the past and is probably capable of producing much increased yields at many points from N. Carolina to the Gulf of Mexico. Experiments have recently been made in relaying clams to get better growth and preliminary results have been encouraging (Menzel and Sims 1962). The artificial production of seed hard clams is also being done on a semi-commercial scale which could substantially increase production once it is developed on a large scale. It would seem probable that production by greater exploitation of *M. campechiensis*, transplantation and artificial rearing could result in annual yields being more than doubled.

The surf clam, being harvested in rather deeper water, does not lend itself to cultivation methods, but there is little evidence that is being over-exploited and it is probable that there are stocks of commercial density still to be found. In Canada it is estimated that yields of this clam could be trebled (Ricker 1962) to around 1,000 tons.

Soft clams are gathered from Canada to a little south of Chesapeake Bay and are now in many areas harvested by hydraulic dredge which has increased yields and decreased damage to the shells (Manning 1957). Production in some areas has decreased as a result of too heavy fishing and lack of sound management (Dow and Wallace 1961). However, with scientific management yields could be substantially increased and statilised, probably at around 50,000 tons (weight of meat) or about a third of a million tons live weight.

At present only about 300 tons of ocean quahog are fished, but MacPhail and Medcof (1959) have shown that there are vast resources of this large deep water clam. It is believed to be one of the most abundant shellfish of the US east coast and can be harvested readily with hydraulic dredges. In exploratory dredging yields of 75 bushels/day were obtained. This species has a very strong flavour which has made marketing of the plain canned product difficult. However, this problem appears now to have been overcome in two ways, firstly by using minced quahog meat combined with pulverised fish flesh, starch and spices in a product called Clombo (Anon. 1967), and secondly by freezing, where the characteristic flavour has proved advantageous. Commercial production is expanding in Rhode Island and adjacent areas. Potential production of this species is probably well above 50,000 tons of meat per year, as some of the potential areas have not yet been explored.

Mussels: *Mytilus edulis*: 1,400 tons - USA

The harvesting of mussels for human consumption in this area has never been on a very large scale although US production was around 4,000 tons in 1908 (Field 1922). Field reviewed the biology and economic value of the mussel and concluded that there were over 1,000 acres (400 ha) in the Massachusetts-Rhode Island-New York area carrying at least 2 million bushels (70 million l) of marketable mussels and likely to be productive grounds elsewhere that he had not visited. Replenishment of stocks appeared to be very good as great areas were covered with small seed mussels.

With modern methods of cultivating and harvesting mussels on the flat, as developed in Holland, the output in the northern half of the USA could be very great, probably exceeding 100,000 tons. At the present time lack of markets prevents any development of this species.

Growth of mussels in Canadian waters would be slower but it would seem worth investigating the possibility of mussel culture there.

Oysters: 327,500 tons

Eastern oyster: Crassostrea virginica: USA, Mexico, Canada

The eastern oyster, Crassostrea virginica, is the only oyster harvested or cultivated in any quantity on the Northwest Atlantic seaboard where its range extends from the St. Lawrence River, Canada, to the Yucatan in Mexico.

Oyster production of the eastern seaboard of the USA reached a peak towards the end of the last century when some 175 million lb of flesh was sold a year, equivalent to about 1.56 million tons live weight (Engle 1964). About 90% came from Chesapeake Bay, the mid Atlantic states, and New England.

During the past 60 years production has fallen to 325,000 tons live weight largely due to a decline of about 80% in these three areas.

There has also been a decline in the Canadian production from around 4,500 tons in 1946/50 to 1,600 tons in 1966, but production from the southern half of the area has been maintained.

The causes of this decline are complex but according to Engle (1964), Galtsoff (1964) and Newcombe and Menzel (1956), the decline in the Chesapeake and neighbouring areas has been primarily due to over-fishing and predators supplemented by disease, pollution and restrictive local legislation which have hampered the development of private cultivation and predator control. MSX disease has also caused considerable losses over a number of years in the high salinity areas. However, the fact that the meat content of oysters in South Carolina has steadily decreased from 39 oz/bushel prior to 1935 to under 30 oz/bushel since 1948 (Lunz 1950) suggests that there may have been other biological factors involved. In Canada the reduction in production has been largely due to disease (Ricker 1962, Medcof 1961) which, in spite of very intense research, is not yet fully identified.

There seems little doubt that the areas which have produced the large yields before could again give at least the same production if seed supply was maintained and the fishery generally modernised regarding tenure of holdings, control of pollution and the full use of available scientific knowledge (Engle 1964).

Recently experiments have been made in Massachusetts (Shaw 1962) to try the use of hanging culture for growing C. virginica. The time for growth to a marketable size was about halved and predation was much reduced and it was concluded that rafts could well have an important place in oyster culture in this, and presumably other areas, in the eastern USA.

C. virginica is now being reared artificially on a large scale in the Long Island Sound area where the seed oysters produced from the basis of a substantial industry using scuba divers for supervising pest control measures and yielding in 1968 some 40 million oysters. The first commercial hatchery in Canada was set up in Prince Edward Island in 1968 (Medcof 1969 personal communication) following intense experimental work in the area (Drinnan and Parkinson 1967).

Glude (1961) suggests that the future oyster production of the USA could increase substantially with the full application of scientific methods to cultivation methods in the sea and ashore.

Ricker (1962) considered that with the development of adequate reliable resources of seed oysters, and more intensive cultivation, Canadian east coast production could reach 7,500 tons live weight per annum.

Butler (1954) in reviewing the state of knowledge on the oyster in the Gulf of Mexico pointed out that *C. virginica* was present throughout the area and its very great abundance was at times an embarrassment to the oyster producer due to the difficulty of producing good shaped oysters when they grow in dense clumps.

There has been wasteful gathering and destruction of grounds in the past but Butler suggests that there are some 1,400 mi^2 in the Gulf capable of producing oysters and a large proportion of this area could produce an average of 300 bushels/acre/year.

He suggests that the production could without great difficulty increase 40 times, from the current 23 million lb (12,000 tons) of meat to around 500,000 tons of meat per year.

It would appear that if the spat settlement could be controlled to give readily singled seed the Gulf could be a major seed producing area supplying growing-on-grounds on a large scale. The above production figures do not take into account the possible advantages of hanging culture which would help to solve the major problems in some areas of predation by such gastropods as *Thais*.

Production of oysters on the east coast of Mexico is of the order of 1,000 tons, but it is not recorded separately from the greater west coast production. Both Lindner (1950) and Carransa (1962) consider that there is a much greater potential and Lindner stresses the need to give attention to seed production. Five thousand tons is probably an under-estimate of the potential with good cultivation.

Gastropods

Periwinkle: *Litterina* spp.: 100 tons - USA

Conch: *Strombus maximus*: 1,800 tons - USA

The catches of gastropods are small due to lack of interest in this group. Whelks are abundant in the north and caught on Georges Bank, but not retained. There are no abalones of commercial size in the area (Cox 1962).

There is little doubt that considerable quantities of this group are present and there would appear to be considerable scope for investigating their potential and markets.

Region IV - Caribbean: 8,300 tons - islands and mainland, excluding USA and Mexico

The Central American Caribbean coast and the offshore islands carry a very great variety of molluscs widely collected for the size and beauty of their shells, but few are exploited for food. While a range of potential food species appears to be present, few if any appear to occur in dense or extensive beds suitable for large scale exploitation and only the conch is widely used.

Gastropods: No records of landings available

Conch:	*Strombus gigas*
	Strombus costatus
West Indian top shell or whelk:	*Cittarium* (*Livona*) *pica*

Conchs are common throughout the area and *S. gigas* is an important source of protein on the Bahama Islands where considerable but unknown quantities are landed. Smaller quantities are caught on the other islands and on the mainland especially Honduras.

The large mean size of virtually all *Strombus gigas* landed suggests that exploitation is nowhere intense and considerable increases in production would be possible.

The West Indian top shell is widely dispersed through the Caribbean and forms a staple local food (Voss 1968). It forms a small fishery in Honduras where it is used for chowders. Voss suggests that the exploitation of this species could be considerably increased.

Scallops: No records of landings available

Small numbers of an unrecorded scallop are landed in the Bahamas. The potential landings of scallop are unknown.

Clams, Cockles and Arc shells: 4,300 tons

Arc shell: *Arca occidentalis*: Venezuela, Puerto Rico

Hard clam: *Donax denticulata*: Honduras

The only fishery for clams for which landings are recorded is that in Venezuela for the arc shells (pepitonas and pata de cabra), but intertidal clams are also fished on a small scale in Honduras (FAO/UN 1963) and Puerto Rico (Fiedler *et al.* 1957).

Menzel (1968) suggests that there is a good possibility of establishing clam fisheries based on artificially reared American hard clams (*Mercenaria mercenaria*) or hybrids between this and the more southern species, *M. campechiensis*.

The extensive beaches and lagoons between Mexico and Venezuela can be expected to yield substantially greater landings of clams than are obtained at present and could also be used for culture based on artificial rearing.

Mussels: 300 tons

Perna perna: 300 tons - Venezuela

At present mussels are only exploited in Venezuela where the fishery is on a small scale from natural beds and the mussels are used for canning and direct consumption. Since 1960 experiments have been made to try out raft culture, but so far there have been problems with making durable rafts, obtaining adequate quantities of seed mussels and adequate quality of the meats (Martinez Escarbassiere 1968). It is difficult to forecast the success of large scale mussel culture as the quality of the product will depend to a great extent on the adequacy of the food available in the water to produce good meats. High temperatures alone can result in rapid shell growth which may not be backed up by the fattening of the edible parts.

Oysters: 3,700 tons

Mangrove oyster: *Crassostrea rhizophorae*: 3,700 tons - Cuba, Venezuela

The mangrove oyster is a small species present throughout the Caribbean and growing attached to mangrove aerial roots. Natural stocks are exploited in Cuba and Venezuela and in both countries attempts are being made with some success to introduce cultivation (Nikolic and Meléndez 1968, Vales 1968). Very heavy settlements of young oysters are recorded in some lagoons in Puerto Rico (Fiedler *et al.* 1957).

There would appear to be considerable scope for improving the cultivation of the mangrove oyster, though its small size will militate against a substantial increase in yield. The possibility of introducing faster growing warm water species such as *O. chilensis* or *C. virginica* should be considered provided artificially reared stock is available to avoid introducing pests and diseases. Also the problem of producing good quality meats may occur.

Actual landings of molluscs in the Caribbean are probably around 15,000 tons and could probably be doubled by a more effective use of existing stocks of conchs and clams. The potential development of fast growing species such as raft grown mussels and introduced oysters is uncertain until experiments have been made to establish whether the relatively poor phytoplankton production will be adequate to produce good quality meats. If this proves successful the production of molluscs could be increased greatly.

Region V - Central and Southeast Atlantic: reported production 1,600 tons - Morocco to South Africa

FAO fisheries statistics covering African countries from Morocco to South Africa inclusive give only 800 tons of oysters for Senegal, 100 tons unnamed molluscs for Sierra Leone and 700 tons of abalones for South Africa.

It is probable that considerable quantities of molluscs are gathered at many places along this coast for local consumption but that the landings are not recorded at all or not separately from other marine products.

Scallops

No commercial species of scallop are recorded but it is probable that they will exist in the cooler waters of Southwest Africa and exploration for them would be worth undertaking.

Clams

No information has been found on the utilisation of clams, but no doubt there are intertidal bivalves worth exploiting particularly in the cooler areas of South Africa, Southwest Africa and on the coast of Morocco.

Mussels

No information is available.

Oysters

A number of species of oyster occur round the coast of Africa but all are small species and of limited commercial value. The species exploited in Senegal is not known. Korringa (1956) examined the potential for developing oyster cultivation in South Africa and concluded that of the native species, *Crassostrea margaritifera* and *Ostrea atherstonei* were the most promising, but suggested that the introduction of the Portuguese oyster, *C. angulata*, should be tried. He considered that there were a number of coastal lagoons that might be suitable for oyster culture but that Knysna Lagoon was the most promising. Productivity of these lagoons was considered to be high, but no estimate was made of potential production.

Gastropods

Abalones are recorded all along the coast of Africa and 700 tons are gathered in South Africa. It would appear that the fishery for abalones might be very considerably expanded in South Africa and developed in other areas.

There can be little doubt that there are mollusc resources and possibly substantial ones, along this long coastline that includes sub-tropical and temperate areas as well as tropical ones, that are available to be exploited. However, if exploration does show a dearth of useful species then the introduction of appropriate ones should be considered.

Region VI - Southwest Atlantic: reported production 10,000 tons - Guyana to Argentina

Scallops: 200 tons

Chlamys (Argopecten) purpuratus

Pecten patria

Small quantities of scallops are landed by Argentina. Reported landings reached a peak in 1964 of 800 tons, but subsequently decreased to 200 tons in 1966. The cause of the decline is not known (Cordini 1961, Carcelles 1947). From the geographical position of Argentina considerable stocks of large or smaller scallops would be expected.

Clams, Cockles and Arc shells: 2,000 tons

Almeja: *Plateria rostrata*

Mesoderma mactroides

Chione antigua

Amiantis purpurata

Many clams are mentioned by Carcelles (1947) and Cordini (1961) as occurring along the coast of Argentina but they do not occur in the landings; while 2,000 tons of unspecified clams are landed in Brasil. There must be very substantial unexploited stocks along the coast of Argentina and no doubt greater yields could be obtained from Brasil.

Mussels: 6,200 tons

Cholga: *Aulocomya ater*: 5,900 tons - Argentina

Mejillones: *Mytilus platensis*: Argentina - 300 tons; Uruguay

The fishery for cholga is done primarily by hand gathering while the mejillones are largely harvested by beam trawls (Cordini 1961). More information is required on the extent of current stocks and their potential for development, but if the demand was present there seems little reason to doubt that production could be very considerable.

Oysters: 300 tons

Ostrea spreta: 300 tons - Brasil

Ostrea puelchana

Ostrea spreta is a small oyster of 50-55 mm occurring throughout the area while *O. puelchana* which reaches 80-85 mm is limited to Argentina and southern Brasil. Both species are considered suitable for exploitation with *O. puelchana* being of particular value for cultivation (Ageitos de Castellanos 1957).

Gastropods

There are no recorded landings of any gastropod from this area. Abalones are not present in this area but there will certainly be other species suitable for exploitation.

B. INDIAN OCEAN: total production 2,000 tons - South Africa to Burma

Published information on landings of molluscs from East Africa, Madagascar, the Arab countries, India, Pakistan and Ceylon amount to only 1,400 tons from Ceylon most of which is probably pearl oysters and 500 tons from India with no information on the species concerned. By contrast, recorded production for Malaysia, with similar conditions to many Indian Ocean countries, was 20,900 tons, mainly from cockle culture.

Along the east coast of Africa and the coasts of India and Pakistan there must be very substantial unrecorded gathering of molluscs for personal consumption or for sale in local markets.

Region VII - Western Coasts - Africa and Arabia

Petit (1930) records a number of species of gastropod, clam, oyster and mussel that are gathered for food in Madagascar, but there are no details of the yields of each or of all the species together. It appears that any molluscs used are gathered by hand. There is no indication of the potential of the island.

No data have been obtained for the East African or Arab countries.

Region VIII - Northern Coasts - West Pakistan to Burma

It is evident that there is a very considerable variety of edible molluscs on the coasts of India, Pakistan and Ceylon, but authorities (Rao 1958, Panikkar 1966) agree that while they form a valuable subsistence fishery, especially when the fishing boats are unable to get out, the resources are only lightly exploited. Panikkar (1966) writes that in the Indian Ocean molluscs offer great scope for the future as they are capable of giving very high yields from the shallow coastal areas of the tropical seas. However, little information is available on the fisheries for the different species available.

In the reply to a questionnaire on edible molluscs organised by the Indo-Pacific Fisheries Council (IPFC/C58/WP 19) the following species were listed as frequently used for food in India:

Clams:		
Cockle clam:	*Crafarium tumidum*	muddy area, south-east
Cockle clam:	*Circe scripta*	muddy area, south-east
Thich shelled clam:	*Meretrix meretrix*	widespread
Common backwater clam:	*M. casta*	abundant
Black clam:	*Villorita cyprinoides*	west coast estuaries
Long siphoned clam:	*Katelysia opima*	widespread
False clam:	*Paphia marmorata*	surf-zone
False clam:	*P. malabarica*	surf-zone
Ridged clam:	*Mesodesma glabrotum*	surf-zone
Large wedge clam:	*Donax scortum*	surf-zone
Small wedge clam:	*D. cuneatus*	surf-zone, abundant
Razor shell:	*Sanguinolaria diphos*	estuarine
Arc shell:	*Arca granosa*	muddy bays
Mussels:		
Green sea mussel	*Perna viridis*	widespread
Brown sea mussel		Kerala area
Oysters:		
Common oyster:	*Crassostrea madrasensis*	abundant in estuaries
Rock oyster:	*C. cucullata*	east and west coasts
Flat oysters:	*C. discoides*	Bombay coast
Crenulated oyster:	*C. cristagalli*	east and west coasts
Gastropods:		
The little bottom shell:	*Umbonium vestiasium*	Bombay coast
Rock whelk:	*Thais bufo*	rocky coasts
Rock whelk:	*T. rudolphi*	rocky coasts
Chank:	*Xancus* spp.	extensive beds

Scallops:

No reference has been found to any scallops being exploited. If there is no fishery this may be due to any scallops occurring being a little offshore and, therefore, not known to those fishermen simply gathering shellfish along the shoreline and in estuaries.

Clams:

In his brief description of the molluscan fisheries of the west coast of India, Rao (1958) states that the clams, *Meretrix casta*, *M. meretrix*, *Katelysia* sp. and *Villorita cyprinoides* are the principal species gathered, all being predominantly estuarine species and abundant in many of the backwaters. Rahaman (1965) refers to the clam *Donax cuneatus* occuring widely in the Madras area and beyond and suggests that it could be much more widely used. Alagarswami (1966) reports that *Donax* spp. are very common in the Gulf of Mannar, Southern India, but are only lightly exploited. The main species is *Donax faba* which grows fast to about 22 mm and is commonly found in the area at 100 to 200/m², but *D. cuneatus* and *D. incarnatus* are frequently found in the same area. The Sind coast includes a network of saltwater creeks extending for some 120 mi where clams and oysters could be more intensely used (Qureshi 1954), and possibly cultivated.

The Razor shell *Solen kempi* is the basis of a local fishery in Mahrasha State on the west coast of India (Rao *et al.* 1965).

Mussels

The green mussel (*Mytilus viridis* - *Perna viridis*) is widely distributed on the east and west coasts of India, while the brown mussel is limited to the southern part of India (Rao 1958). Both species are very good food and form a subsistence fishery of considerable but unknown magnitude (Jones 1950, 1968). They are common in the intertidal zone and to a depth of about 6 m wherever the coast is rocky, and are gathered by hand where exposed and by diving as these are depleted, using a wooden-handled chisel. Growth is fast, mussels settling in June being 6-8 cm long and ready to harvest during the following winter months, December to May.

In Tellicherry, which is probably the most important centre, some 2¼ tons are landed a day by a fleet of 30 dug-out canoes. There is a great demand for the mussels and there is clearly the basis for a very substantial development of this fishery by the introduction of simple cultivation methods which increase the available stocks. There are problems of preservation of this very perishable product under these hot conditions, but these are being investigated (Jones 1968).

Oysters

Four species of *Crassostrea* are widely present in India - *C. cucullata* is common on rocky coasts, *C. discoides* occurs on the litoral zone of coastal areas, while *C. gryphoides* and *C. madrasensis* are to be found in the estuaries (Rao 1958). Durve and Bal (1962) have studied the growth rates of the latter two species and find that *C. gryphoides*, which is common on the west coast reaches a marketable size of 6-7 cm in two years while *C. madrasensis* reaches 7 cm in 1½ to 2 years and is usually marketed at the end of the second year of growth or in the middle of the third year. In spite of their general abundance, in most areas the oysters are not extensively used. However, there is a tradition of oyster growing in parts of West Pakistan (Khan 1962) in which seed oysters were transplanted to good growing areas, but current production is low.

With these fast growth rates and the normal abundance of these species there would, as with mussels, appear to be the basis for greatly expanded usilisation and cultivation.

Gastropods

The only information found is that gastropods are only spasmodically gathered for food and that the most important are probably *Thais* spp., *Umbonium vestarium* and *Natica* spp. (Rao 1958). There would, therefore, appear to be considerable scope for increased fishing on this group.

C. PACIFIC

Region IX - Northeast Pacific: reported production 50,400 tons - Alaska to Mexico

Scallops: No recorded landings

Bay scallop: *Pactinopecten carinus* - Alaska

The only species of scallop recorded in quantities sufficient for exploitation is the Bay scallop which has been the subject of exploratory fishing in the Gulf of Alaska in very recent years. Scallops have been found to occur throughout the surveyed area from Alaska/Canadian boundary to Kodiak Island and catches have reached 7 bushels of large scallops for a 45-min. haul with two 3.5 m dredges (Haynes and Powell 1968). It is expected that a substantial fishery can be developed for these scallops which might eventually rival the Georges Bank fishery and yield between 10 and 100,000 tons live weight.

Clams, Cockles and Arc Shells: 2,800 tons

Butter clam (northern):	*Saxidomus giganteus*: British Columbia, USA, Alaska
Butter clam (southern):	*Saxidomus nuttali*: USA
Razor clam:	*Siliqua patula*: Alaska, British Columbia, USA
Little neck:	*Protothaca staminea*: British Columbia, USA
Japanese or Manila clam:	*Tapes semidecussata*: USA
Pismo clam:	*Tivela stultorum*: USA, Mexico
Gapers:	*Tresus nuttali*: USA
Soft clam:	*Mya arenaria*: USA
Geoducks:	*Panope generosa*: British Columbia, Mexico
Jacknife	*Tagelus californeanus*: USA

Although some 35 species are considered as edible (Amos 1966), only a few species are harvested on a large scale to enter state statistics, about 80% of the landings being made up of five, the butter clam (two species), razor clam, little neck and Manila clam. While the recorded landings are 2,800 tons, these are all from the commercial fisheries and it is probable that a further 2,000 or more tons are gathered in the sport fishery which is very popular in the USA and particularly in California and Oregon.

In Alaska there are considerable quantities of clams, especially butter clams and razor clams and Quayle (personal communication) puts the potential production of clams from that state at about 6,000 tons, though there is periodic paralytic shellfish poisoning which will make their use, and particularly that of butter clams, difficult.

Ricker (1961) estimated that the potential clam production of British Columbia is about 2,300 tons comprising 1,600 tons of butter clams, 470 tons of little neck clams and 230 tons of razor clams. A more recent estimate by Quayle (personal communication) gave the slightly higher figure of 3,000 tons for the three species. The largest Pismo clam is limited to California and Mexico and while it is harvested in considerable numbers in Mexico (600 tons) it does not appear to be capable of supporting a large fishery in California, stocks having been rapidly reduced when large scale gathering started, and the fishing is now restricted to sport fishing only.

It is probable that the yield of gapers (*Tresus nuttali*), butter clams, little necks and the Manila clam can be increased in the Washington and Oregon areas but with conventional methods it is not likely to increase greatly.

Glude (1968) considers that clam production in the Pacific coast of the USA can be helped by the development of private clam farming for butter clams, little neck and Manila clams, while razor clams and pismo clams are best kept as public resources.

At present nearly all the clams on the west coast of America are harvested by raking and digging in the intertidal zone and as a number of the important species including pismo, razor, butter clams and gapers extend well below low tide level, it can be anticipated that the development of mechanised methods of harvesting including dredges based on the hydraulic principal would increase the yields from the intertidal zone as well as make available what are probably very substantial resources from below low tide level.

If these methods were available the yields from the area might be expected to reach 20,000 tons.

Mussels: No recorded landings

Mytilus californianus is very common throughout the area but there is no tradition of eating mussels and few are harvested except for personal use.

It is probable that very substantial annual yields in the order of 10,000 tons would be possible from harvesting present stocks, with some relaying at low tide levels to get good fattening, if the markets were available. However, there is the problem of paralytic shellfish poisoning, particularly in the northern part of the area, which could restrict sales to the winter months or require a monitoring service to ensure that toxic mussels were not sold.

Oysters: 38,600 tons

Pacific oyster: Crassostrea gigas: 38,000 tons - British Columbia, USA, Mexico

Eastern oyster: Crassostrea virginica: 100 tons - USA

Olympia oyster: Ostrea lurida: 15 tons - USA

The native oyster of this coast is the Olympia oyster (O. lurida) a small species which is only abundant in Puget Sound where it still forms the basis of a small fishery. The fishery is maintained in a good state as the flavour is much esteemed and it fetches high prices. It is likely in the future to contribute more than a few tens of tons to production as large scale oyster production is now firmly based on the very productive Pacific oyster.

The Eastern oyster was imported to California in 1869 and Washington in the 1880s where it formed the basis of a flourishing industry in both states (Barrett 1963). Production in California fell drastically after 1904 due to pollution of the two main production areas, San Francisco Bay and San Diego Bay, but has recently been reestablished on the basis of imported Pacific oyster seed from Japan to Humboldt, Tomales, Drakes and Morro Bays. Annual production runs at about 4,000 tons. The Pacific oysters fail to spawn in California waters and therefore the fishery remains dependent on imported seed. In Washington the Pacific oyster from Japan has also replaced the Eastern oyster and production based on Puget Sound, Willapa Harbour and Grays Harbour, the three main inlets, is running at 27,000 tons; 5,000 tons of Pacific oyster are also produced in Oregon. Experiments are proceeding to increase the proportion of locally produced seed as the supplies from Japan are costly and not always satisfactory.

In British Columbia only Pacific oysters are grown and the current yield of 5,700 tons is largely from imported Japanese seed.

In all these areas cultivation is based on growing oysters on the bottom by traditional methods, but experiments are being carried out in British Columbia and Washington to increase local seed supply by artificial collectors suspended from rafts and these are meeting with considerable success. The artificial rearing of Pacific oysters by a private company is progressing in California with the aim of overcoming the seed supply problem there.

If these experiments are successful and an adequate supply of seed oysters is assured the production will be able to increase substantially and will be primarily limited by demand. While official statistics show a total production of 38,600 tons for 1966 from this area, Quayle (personal communication) estimates that in 1968 the production on the whole of the Pacific North America coast is running at 60-70,000 tons (British Columbia 9,000 and USA 45,000 tons) and that this total could be doubled with the right economic stimulus and adequate supplies of seed at acceptable prices.

Experiments to rear the European flat oyster Ostrea edulis are being carried out in Alaska (Haynes and McCrary 1967) and in Washington (Westley 1967) to supplement local production. In California commercial growers have recently begun culture of European flat oyster in Drakes, Estero and Morro Bays.

Gastropods: 9,000 tons

Pink Abalone: Haliotis corrugata - Mexico, USA

Red Abalone: H. rufescens - Mexico, USA

Green Abalone: H. fulgens - Mexico, USA

Pinto Abalone: H. kamchatkana: few - British Columbia

The only gastropods caught in any quantity are the abalones and the 9,000 tons produced annually are based about equally on three species, the red, pink and green abalones.

There are no abalones on the mainland of Mexico and none in the Aleutian Islands (Cox 1962). Two species H. *kamtchatkana* and H. *walallensis* extend from Southern Alaska to California, but are not sufficiently abundant to form important fisheries (Livingstone 1952, Quayle 1962). Eight species occur in Californian waters and most extend south along Baja California, but no further. Only red, pink and green abalones are sufficiently large and abundant to make a substantial contribution to landings, the pink and green being most important in Mexico and the red and pink in California. All harvesting is done by diving along exposed coasts from the intertidal zone and down to some 60 ft, though both red and pink abalones do extend to considerably greater depths, but in reduced numbers. It is unlikely that any substantial catches will be possible for the species other than the three that are at present important, but with these there does not appear to be evidence of too heavy exploitation and yields could probably be increased by 50% or perhaps doubled by more intense fishing while maintaining suitable minimum size limits. The variety of local legislation relating to fishing for abalones appears to be unnecessarily restrictive.

Region X - Northwest and Western Central Pacific: reported production 830,000 tons - USSR to Malaysia

This very extensive area includes several countries with very great landings of molluscs; Japan lands 550,000 tons, Korea 107,000 tons and Thailand 102,000 tons, while Malaysia, Taiwan and the Philippines land between 10,000 and 25,000 tons each. Furthermore, no information is available for Mainland China or the multitude of smaller Pacific islands and some of the larger ones and little for the Pacific coast of the USSR.

Scallops: 10,200 tons

Pecten yessoensis: Japan: 7,400 tons; USSR: 3,500 tons

The catch of scallops in Japan declined from 19,000 tons in 1958 to a minimum of 5,700 tons in 1965; the 1966 catch was slightly higher. The reasons for these changes are not known but may be due to variation in year-class strength. In Japan a considerable number of scallop spat are settled onto suspended shell collectors from which they may be transported considerable distances for relaying (Cahn 1951), but this apparently has not reduced the fluctuations in abundance of the grown stock.

The USSR catch is from the area south of the Kuril Islands (Ivanov and Strelkov 1949).

There is little doubt that this species and probably other scallops occur in commercial quantities in other parts of the western Pacific. Exploration for scallops off Taiwan (Formosa) would be worth attempting.

Clams, Cockles and Arc Shells: 244,800 tons

Asari:	*Venerupis semidecussatus*: 129,000 tons - Japan: 110,000; Korea: 19,000
Hamaguri:	*Meretrix meretrix*: 16,300 tons - Japan, Korea
Hokki-gai:	*Mactra sacchalinensis*: 8,700 tons - Japan
Magai, cockle:	*Anadara subcrenata*: 45,000 tons - Japan 36,500; Korea 8,000
Kerang:	*Anadata granosa*: 24,500 tons - Malaysia

Over most of the world clams are harvested with little or no cultivation or conservation, but in Japan, Korea and other parts of the area the gathering of spat from areas where the young have settled from the plankton in great numbers and are very dense and relaying them at lower densities in areas where they will grow fast is the standard form of cultivation. This procedure takes full advantage of the fact that the settlement of many of these molluscs is typically very patchy, locally very dense and often in areas where the best subsequent growth is not obtained. If left unthinned at the high densities growth can be considerably reduced. In Japan (Cahn 1951) this transplanting of the seed clams (often only a few millimetres long) to private lays, is standard practice with *Meretrix meretrix*, *Venerupis semidecussatus*, *Anadara subcrenata*, *Anadara granosa* and *Atrina japonica*. It is probable that this method which has also been found successful for *Anadara granosa* in Malaysia (Pathansali and Soong 1960) could be even more widely used with success. In Malaysia this method started in 1948; total production reached 24,500 tons in 1966 and is still increasing.

The present techniques depend on a great deal of manual labour and while this may still be economically acceptable in some countries it is not likely to be acceptable when the standard of living rises or in countries where wages are already high. However, it is probable that the harvesting of these young clams could be done even more efficiently and with less mechanical damage if hydraulic type dredges were developed to meet the situation.

Mussels: over 55,000 tons - Thailand: over 50,000 tons; Korea: 4,700 tons, USSR

Mytilus smaragdinus

Mytilus crassitesta

The two main species of mussel harvested in the Northwest Pacific do not produce a major fishery anywhere on the scale that *M. edulis* does in Europe, or the mussels in Chile. Cahn (1951) suggests that in Japan this is due to the much greater popularity of other molluscs.

In the Philippines, however, the programme of development of mussel culture, using *M. smaragdinus* has been progressing for 7 years and the results are encouraging though no annual yield figures are available. Backiel (FAO Fisheries Travel Report FRi/TRAM/95) reports that it is estimated that the yield will be around 100,000 gall/ha/year. *M. smaragdinus* is also indigenous in Malaysia, and both environmental and economic factors for large-scale culture, on the flat, or hanging culture seem favourable.

The recorded production of molluscs for Thailand is 102,000 tons but this is not broken down into species. However, it is believed that about half of this total is of mussels. There seems to be no reason why mussel culture should not be carried out on a large scale in many countries in this area, but there does not appear to be the demand at present.

Oysters: 263,000 tons - Japan: 231,000 tons; Korea: 51,700 tons; Taiwan: 10,300 tons; Philippines

Crassostrea gigas: Japan, Korea, Taiwan

Ostrea rivularis: Japan

O. denselamellosa: Japan

O. nippona: Japan

O. echinata: Japan

O. iredalei: Philippines

O. malabonensis: Philippines

O. palmipes: Philippines

Where there are some 17 species of oysters in the Northwest Pacific and small quantities of 5 species are harvested in Japan, *Crassostrea gigas*, a very fast-growing easily grown and palatable oyster accounts for well over 90% of the annual production of all countries in the area.

Oyster culture has reached a higher stage of development in Japan than in any other country, but there is still present all stages of development of the culture from the harvesting of the oysters untouched from the time that they settled as spat on stones or shells, to a carefully controlled system one of the main features of which is the separation of the production of the seed from the growing on and fattening of the product for market.

Production of oysters for food in Japan is now running at around 240,000 tons a year, apart from the considerable quantities of seed oysters exported to other countries, and has remained at this level for four years. It is probable that this output is near the maximum as most suitable areas for rafts are already taken up and it is found that there is need to move the rafts at intervals or output decreases.

However, in Korea cultivation of natural beds is being increasingly supplemented by raft style collectors for seed production (Kim 1962a) and output exceeded 50,000 tons in 1966. The output has been increasing very rapidly and seems probable to continue to do so.

In the Philippines oyster culture is being encouraged by the Philippines Fisheries Commission Programme and 1,000 ha in Manila Bay are now leased in small plots to private growers. There are 1,000 acres leased for oyster cultivation in other regions all over the country (Backiel FRi/TRAM/95). It is considered that the possibilities of further expansion of oyster culture are limited in Manila Bay and other areas by the shortage of suitable grounds and that the 1966 production of about 20 million baskets/year is probably about half of the potential.

Taiwan has a production of 10,300 tons and Tiews (1965) has recommended that Thailand should further develop its oyster culture.

It seems most probable that there are many sheltered areas suitable for oyster cultivation both on sticks and with hanging culture throughout the Southeast Asia complex of islands and coastal mainland waters and the total production of the area could be several times even the present high output.

Gastropods: 18,500 tons - Japan: 12,500 tons; Korea: 5,400 tons; Malaysia: 500 tons

Abalone *Haliotis gigantea*: Japan, Korea

H. kamtschatkana: Japan

H. diversicolor: Japan

Turbo cornutus: Japan, Korea

Strombus canarium: Philippines

Melongena spp.: Philippines

Abalones are present throughout the area and might be expected to be capable of considerably greater yields. Much greater catches would also be possible for the variety of other gastropods available in the area.

Region XI - Southeast Pacific: reported production 51,000 tons - Panama to Chile

Scallops

Ostion *Chlamys* (*Argopecten purpurata*): few - Chile

Intensive fishing of the ostion in the area Valparaiso to Coquimbo (Chile) has lead to severe reduction of stocks and commercial fishing has been prohibited between Arica and Valparaiso since 1958. It is probable that this and other species occur fairly widely along this coast.

Clams: 9,700 tons

Taca, almeja or hard clam: *Protothaca thaca*: Chile

Almeja: *Eurhomalea sp.*: Chile

Almeja: *Ameghinomya sp.*: Chile

Macha, soft clam: *Mesodesma donacium*: Chile

Several species of hard clam (almeja) are fished throughout Chile with the Chiloe area being the most important. The soft clams (macha) are also widely distributed along the coast of Chile but are exploited chiefly in the central zone.

The potential of these species has not yet been assessed for Chile but it is certainly far greater than is being realised at present. There are also likely to be substantial stocks of these and other clams and cockles along much of the coastline of Peru and probably also Ecuador and Colombia, both intertidally and for some distance below low water mark.

Exploration for commercial concentrations of clams along those parts of this long coastline that are shallow and sandy would probably be rewarding.

Mussels: 22,700 tons

Cholga: Aulocomya ater: Chile

Chorito: Mytilus: Chile

There is virtually no mussel fishing in Colombia or Peru. Some sublitoral cholga are taken in the north of Chile and experiments in raft culture are being made in this area.

However, south of Puerto Montt the Chilean coastline comprises very many islands and deep fjords with some shallow bays. Here there is a substantial production of the cholga mainly gathered by diving. Stocks of cholga and chorito in the Chiloe area have almost been exhausted, but some virtually unexploited areas still exist south ot the Golfo de Penas. The very large mussel or choro (Choromya choro) has in the past formed a useful small fishery (379 tons in 1962), but the stocks were reduced by heavy fishing and since 1961 commercial fishing has been prohibited as a conservation measure.

Attempts are now being made to expand the mussel fishery and to develop mussel cultivation and it would appear that this part of Chile is ideally suited to the large scale development of hanging culture. The coastal waters are rich in plankton, temperatures range between 12° and 18°C for most of the year; there is a good tidal movement but not excessive currents and there are hundreds of miles of deep sheltered water.

Investigations are required to determine suitable areas for the settlement of spat and the months when this normally occurs, because the successful large scale culture of mussels will depend to a great extent on the availability of adequate, reliable supplies of seed.

Communications are bad in this area and a viable production may depend on cultivation being on a sufficient scale for the industry to provide its own transport to processing centres.

If these problems can be solved there appears to be no biological or physical limit to the potential production in the area until rafts fill the many miles of sheltered waters. Suitable sheltered areas appear to extend for some hundreds of miles, but further south temperatures are reduced and communications become worse.

Oysters: less than 100 tons

Ostrea chilensis

Ostrea chilensis is present from north of the Equator to the south of Chile and has formed the basis of a small fishery around Chiloe.

The sheltered fjords and bays of southern Chile appear ideal for the hanging culture of oysters and production there could be very great, provided adequate seed were available. The Chilean oyster has an advantage that its pelagic larvae settle almost immediately after they have left the parent, so it may be less difficult than for other species for seed production to be developed on a large scale. This production could provide the basis for a major industry.

The next few years should show how suitable O. chilensis is as a species for culture on a large scale. If despite its advantages a reasonably rapid development proves impossible, it would then seem worth examining the advantages of introducing one of the faster growing Crassostrea species.

As this area, on superficial examination, appears to be one which could become a major oyster or mussel producing area of the world, it would be wise to take precautions lest hasty introduction of adults also brought parasites, etc. that seriously harmed the development of the area.

Gastropods: 3,400 tons

Concholepas concholepas (loco): Chile

The recorded catches of gastropods comprise largely the loco from central and southern Chile, a large gastropod feeding over the surfaces of rocks, which is caught primarily by diving. There may be substantial stocks of this species in the rocky coastline in southern Chile, but due to the difficulty of harvesting it is not likely ever to form a major fishery.

Thais and Buccinid whelks occur in Chile but they are fished only for local consumption and their true potential is unknown.

There are no abalones along this coastline south of Mexico.

Region XII - Australia and New Zealand: 34,000 tons

Scallops: 12,700 tons

Australia

Saucer: *Amusium balloti*: 300 tons - Queensland
Pecten alba: 12,000 tons - Victoria
Doughboy: *Mimachlamys asperrimus*: - Tasmania
Commercial: *Notovola meridionalis*: 400 tons - Tasmania
Queen: *Equichlamys bifrons*: - Tasmania

The history of scallop fishing in Australia has to date been one of intense exploitation of new grounds until the maximum sustainable yield has been exceeded and the fishery has required complete or partial resting for rehabilitation.

The number of dredges around Tasmania has shown fluctuating increase from about 50 prior to 1930 to between 200 and 250 since about 1958. The total yield of scallops by numbers has also increased from around 400,000 in 1930 to 2.5 to 3 million scallops since 1955 (Harrison 1965). However, this expansion has masked several major changes in the fishery. In 1933 the expanding fishery was largely on the moderate sized Doughboy scallop (*Mimachlamys asperrimus*) in the D'Entrecasteaux Channel. These declined and around 1940 the fishery turned to the larger Commercial scallop (*Notovola meridionalis*) which was on the increase in the same area. This species was intensely exploited and catches rose to a peak in 1947, but subsequently fell steadily until 1952. Areas were temporarily closed and catches rose to over 1,000 tons but fell again to a mere 5.5 tons from the Channel in 1964. However, by this time scallop fishing was spreading to other areas on the east and north coasts of Tasmania such that total yields increased and reached 2,600 tons in 1962/3 only to fall again to less than 400 tons in 1965/6.

It would appear probable that with management of effort and minimum sizes a sustainable yield in excess of 2,000 tons/year could be achieved for the coast of Tasmania as a whole.

A similar pattern appears to be developing for the Victorian fishery for *Pecten alba* in Port Philip Bay, where yields increased to 12,500 tons in 1965/6 from virtually nil in 1962/3 and where according to Sanders (1967), the catch per unit effort is continuing to fall steadily and the effor is now too great. The sustainable yield is probably in the vicinity of 10,000 tons live weight.

In Queensland fishing for saucer scallop, *Amusium balloti*, by trawl has developed as a sidelin to prawn trawling and could give substantially greater yields. In West Australia there is little scallop fishing though there is evidence of substantial stocks of saucer scallop in Shark Bay. However, it is probable that there is a series of stocks of several species of scallop around much of Australia and if the minimum sizes and the fishing effort or the yield were controlled to the optimum, the annual yield of the country could probably be maintained in excess of 30,000 tons.

In New Zealand there is as yet no significant scallop fishery, but there is little doubt that stocks of commercial density will exist, for Tunbridge (1962) reported that in the past scallops were as common as oysters in Tasman Bay.

Clams: 120 tons

Australia

Pipis: *Plebidonax deltoides*

New Zealand

Pipis: *Amphidesma australis*:
Cockles: *Chione stuchburgii*:
Toheroa: *Amphidesma ventricosum*:
Tuatua: *Amphidesma subtriangulatum*:
} 1,800 sacks = ca 120 tons

There is no information on clam resources around Australia, but it would be very surprising if there were no exploitable stocks. Exploration work is merited. Only relatively small quantities of clams are landed in New Zealand. Toheroa (Amphidesma ventricosum) on the beaches of North Island (New Zealand) are exploited commercially for canning and by the public for their own use. The yields slumped badly around 1938 due to poor recruitment and fishing is now controlled by closed seasons and quotas, but annual yields are not published.

Rapson (1954) considers that the beaches of the North Island could produce an average 150,000 lb meat, about 120 tons live weight, per year, with substantial fluctuations due to natural causes. Recent surveys by Greenway (1969) have shown that the populations of Toheroa are subject to large and sudden reductions in numbers unrelated to fishing. There is some evidence of sublittoral populations (Waugh and Greenway 1967). Other species of clam are only gathered on a very small scale for personal use, though a recent resources survey suggests that there are substantial resources of cockle, tuatua and pipi, though no estimates of potential yields are given.

Mussels: 2,200 tons

Australia

Mytilus planulatus: 200 tons in 1966

New Zealand

Perna canaliculus: 2,000 tons in 1964

No information has been found on the present fisheries for mussels, or their potentialities, apart from the fact that they are regularly exploited on a small scale in Victoria. Landings in 1966 were only half what they were in 1962/3. The large green-lipped mussel Perna canaliculus (which reaches 16 cm in length) has always been in ready public demand and is found extensively round the New Zealand coast from mean low water of neap tides to at least 10 fm (Greenway 1969a). Landings from dredging in the Firth of Thames give increasing yields until 2,000 tons were reached in 1961, following which the fishery collapsed and ceased in 1966. As one area was depleted, others were fished until all productive areas were depleted. Recruitment appears to have failed, due to removal of all the mussels among which the young ones settled.

Waugh (1969) estimates that there are some 50,000 acres of sheltered water in the Marlborough Sound suitable for the raft culture of mussels and preliminary experiments using P. canaliculus are encouraging as growth is very fast, 10 cm being reached in 18 months. Waugh suggests that an annual production of 260,000 tons might be reached.

An examination of the potential for harvesting and cultivation in both countries would appear to be worth investigation.

Oysters: 16,800 tons

Australia

Sydney Rock oyster:	Crassostrea commercialis: 6,710 tons
Western Rock oyster:	C. tuberculata: 11 tons
Oyster:	Ostrea angasi: 3 tons

New Zealand

Dredged oyster:	Ostrea lutaria: 7,500 tons
Rock oyster:	C. (Saxostrea) glomerata: 200 tons

There has been for many years a substantial industry for the Sydney Rock oyster in New South Wales and the technology of spat settlement on fibro cement slats and their subsequent fattening on racks is well established. Pollution has become a problem but is currently being resolved by the use of cleansing in tanks where necessary.

There has been little attempt to extend oyster cultivation to new areas, though attempts to introduce *C. gigas* from Japan to Tasmania have been encouraging (Thomson 1959). There would appear to be scope for introducing *C. gigas* also to warmer waters than around Tasmania.

There is probably scope for the development of oyster cultivation in Queensland, Tasmania and South Australia where at present there is virtually none.

In New Zealand the fishery for flat oysters is limited to natural beds of *Ostrea lutaria* in Foveaux Strait (southern South Island) where yields have fluctuated between 5,500 tons and 10,000 tons during the last 10 years and is unlikely to produce much greater yields. However, other areas have not yet been exploited though Tasman Bay for instance has been found capable of producing about 400 tons/year (Turnbridge 1962). To date no attempt has been made to farm them, though investigations into cultivation requirements are being undertaken.

Rock oysters (*Crassostrea glomerata*) at present yield some 170 tons from natural grounds on the north east of North Island. This 250 mi coastline has many bays where cultivation of rock oysters on a large scale would appear to be possible. In the Northland harbours, Bay of Islands, Whangerei, the Auckland Harbour-Hauraki Gulf area and Kaipara Harbour, Waugh (1969a) considers there is sufficient foreshore and sheltered water to provide farming space to achieve yields comparable to N.S.W. Australia, i.e. at least 5,000 tons/year.

Gastropods: 1,300 tons

Australia

Abalones: *Notohaliotis ruber*

Schismotis laevigata

Notohaliotis conicopora

Marinauris roei

New Zealand

Paua: *Haliotis ivis*

The fishery for Abalones in South East Australia by diving is rapidly expanding (Anon. 1967) and shows no signs of reaching its maximum. Recent landings have been:

1963/4	70 tons
1964/5	440 tons
1965/6	1,300 tons

The most important species is *Notohaliotis ruber* which reaches 7½ inches in length and can yield over 1 lb of flesh per animal. *Schismotis laevigata* and *Notohaliotis conococpora* are also caught in small numbers in the southeast, while *Marinauris roei* is the commercial species of Western Australia.

Abalones are also present in the waters of Queensland and the Northern Territory and so there appears to be the basis for considerable further expansion of this fishery.

Practically all the catch is frozen or canned and exported to Malaysia, Japan and the USA.

There is no recorded fishery for Abalones in New Zealand though the Paua, which reaches 6 inches (15 cm) across, is gathered locally on a small scale by diving.

No carnivorous gastropods are utilised in Australia or New Zealand.

DISCUSSION

1. PARALYTIC SHELLFISH POISONING (P.S.P.)

From time to time and in widely different parts of the world there occur blooms of certain single-celled plants which produce within themselves a toxin which is taken up by filter feeding molluscs and passed on to the consumer where it can cause serious illness and death. The regularity and severity of the poisonous condition in any area can be of great importance in the utilisation of the filter feeding molluscs of that area.

The organisms producing the toxins are all Dinoflagellates and species of Gonyaulax have been most commonly and certainly shown to be responsible, though species of other genera including Prorocentrum and Exuviaella are believed to have caused poisoning (Shilo 1964, Nakasima 1968). The blooms can develop very locally or over hundreds of miles of coast and may be present for short or long periods of time, and though they are frequently visible by causing a red or orange discolouration of the sea, they do not always do so. The toxin does not harm most molluscs, but is retained in different tissues of the living molluscs from a few days to several months at levels depending on the initial levels, the species and the temperature (Wood 1968).

Mussels have been found to accumulate the toxins to higher levels and to retain them for longer periods than most molluscs and in Europe they have been more frequently the cause of illness or death from paralytic shellfish poisoning than other filter feeders. On the Pacific coast of America where mussels are little used it is the butter clam that has caused most trouble, due probably to the retention of the toxin in the siphons for several months (Magnusson and Carlson 1951).

There is no known method of detoxifying the living or preserved tissues and normal cooking only destroys some of the toxin.

The blooms are most frequent in the temperate to subtropical areas, as seen in Table Q1, but rarely occur during the winter months and in most areas are sufficiently rare not to be a serious factor in the sale of filter feeding molluscs.

However, on the Pacific coast of America the occurrence of paralytic shellfish poisoning is sufficiently common to have prevented the use of the large resources of the butter clam (Saxidomus giganteus) in Alaskan waters (McFarren et al. 1960) and to have necessitated a monitoring system for clams in British Columbia (Quayle 1966). The commercial harvesting of mussels from various parts of the Atlantic coast of Canada is also prohibited seasonally as a result of the frequency of occurrence of unacceptable levels of toxin (McFarren et al. 1960).

In some areas therefore the occurrence of blooms of these particular Dinoflagellates could prevent the utilisation of natural stocks or the development of cultivation of certain filter feeding molluscs (particularly mussels and certain clams) or could necessitate the routine monitoring for toxins and the restriction of sales during periods when the toxins are above acceptable limits.

Table Q? - Known cases of paralytic shellfish poisoning 1793- 1958
(from McFarren *et al.* 1960)

Locality	Year of occurrence	Number of cases	Number of deaths
California	1903, 1915, 1917, 1918, 1927, 1929, 1932, 1936, 1939, 1943, 1944, 1946, 1948, 1954	373	30
Oregon	? 1933	> 22	1
Washington	1942	3	0
Vancouver, B.C.	1793, 1942, 1943, 1957	60	5
Alaska	1799, 1934, 1954	119	103
Nova Scotia and New Brunswick	1936, 1945, 1957	66	2
Maine	1943	> 24	-
Quebec	1948, 1954	9	4
England	1857, 1872, 1888, 1904	> 7	4
Wales, Scotland and Ireland	1827, 1872, 1890, 1909	60	11
Norway	1901	5	2
Prussia	1885, 1887	22	5
France	1907	13	2
Belgium	1940	12	4
S. Africa	1948	several	-
New Zealand	1951	several	-
TOTAL		792	173

Note - This table is only a summary of published information and may therefore not necessarily give a true picture of the relative incidence in different areas. For instance Medcof reports that in eastern Canada poisoning is a more serious problem in Quebec than in Nova Scotia and New Brunswick.

General

The latest statistics available to FAO are summarized in Table Q2. It should be emphasized that much collection and consumption of molluscs falls outside the scope of precise statistical records in many areas especially where there is subsistence fishing; thus under-reporting is certainly not uniform either between areas, or between species groups. However, the pattern shown in Table Q2 of mollusc production is seen to be concentrated in a few areas and on a few species, and is much greater than can be accounted for by any peculiarities in the statistical system. Of the total of 2 million tons, well over half consists of production in two relatively small areas - Japan, and the USA east coast. Of the rest some 20% comes from mussel production in two even smaller areas in the Netherlands and Spain.

Within areas there is a similar lack of uniformity. Mussels make up 60% of the total from the Northeast Atlantic, while in the Southwest Pacific (Australia and New Zealand) the production is almost entirely of oysters and scallops.

These differences are much greater than any real difference in the natural populations, and reflect mainly regional differences in habits and food preferences. The opportunitites for expansion in many areas, if these preferences can be changed, are clearly very large. These have been touched on in the detailed area reviews; in these it was usually impossible to set any very precise limits to the potential in any area. A rough measure of the total potential of the whole world can be deduced from the fact that Japan and the east coast of the USA produce over a million tons of molluscs. These coasts comprise one twentieth of the total world coastline. Twenty million tons would therefore be a very rough estimate of the world potential of molluscs, assuming all coasts were as productive as Japan and eastern USA. In fact the primary production of the waters of Japan and USA are possibly rather higher than the world's coastal waters as a whole, and also cultivation is well developed in these areas. Against this it is probable that the natural production is not fully exploited, at least in the USA. Perhaps 10 to 25 million tons could be taken as a reasonable limit to the potential, if the natural production is fully used, and cultivation generally is brought to the level of that in Japan and USA at present. If cultivation is further intensified the potential is certainly very much higher, especially if the possibility of suspended culture in the open sea is considered, and there is not the information at present available to set even a rough figure to such potential.

Needs for further research

(a) Statistics - Statistical information in many areas is very poor. This is largely due to the nature of fishery, with a large number of individual fishermen concerned, often with primitive methods. Probably the provision of greatly improved statistics would, in many areas, involve a large expense in terms of numerous field staff, etc., an expense which would hardly be justified in terms of the economic value of such fisheries. In some of the more advanced fisheries, where the total production figures are available, additional statistical information on such things as fishing effort (at least for such active methods as scallop dredging), area used in cultivation, etc., would make interpretation of past trends in catches, and estimation of future potential much easier and more accurate.

(b) Natural stocks - Molluscs are moderate sized sedentary animals; quantitative surveys of their abundance are therefore, in principle, easy to carry out. As the references given in this report, though admittedly incomplete, suggest, very few such surveys have been carried out. Though standing crop is not equal to production, the estimation of potential production can be made with reasonable accuracy, once estimates of standing crop and some measure of the rate of mortality and replacement, are available. If better estimates of natural molluscan resources are required, this can most accurately, and probably most cheaply, be done by surveys of the standing crop. Since there is probably a large degree of similarity between the resources of different areas of the same region, such surveys would probably best be done on a regional basis, using a stratified sampling scheme taking into account such obviously relevant factors as type of bottom, depth, exposure to currents, etc.

(c) Cultivation - The biggest potentials for molluscs lie in cultivation. At the present production is very less than the physical potential. This is probably true even in most areas where cultivation is already practiced, while there are large areas of the world where there is no cultivation. The urgent problem is therefore of overcoming the social and economic obstacles to mollusc cultivation, in these latter areas especially, and introducing techniques which are already well known elsewhere. This development would be easier to achieve if better estimates could be set to the physical limit to the production. This requires better information than exists at the moment on the environmental conditions for successful cultivation - depth, type of bottom (except for raft culture), tides and currents, shelter from bad weather, temperature, salinity, primary production, abundance of suitable food, etc.- as well as the potential yield per unit area from such grounds, and the total global extent of each type of suitable ground. The association of engineers with biologists and oceanographers in the development of mollusc culture would also help to achieve successful technologies and avoid costly errors.

While much of the production of seed is now done on artificial collectors, often working in three dimensions, much of the further growing on is done on the flat. However, research and practice in some areas is showing that substantially increased growth and reduced predation can be achieved by growing all stages of oysters off the bottom. If the attachment of oysters to strings, etc., can be done economically the possible production in good growing areas should be much increased.

In the USA and UK experiments are in progress with a view to using the heated effluent from power stations to provide suitable growing conditions throughout the year. Improved strains with better growth rates and other characteristics may be achieved by strictly selective rearing and breeding, including the possibility of producing pure-bred lines by storing sperm and thus mating an oyster with itself. These methods are now producing large quantities of uniform high quality oysters, which are fattened in the natural but carefully controlled predator-free waters in Long Island Sound for supplying to the high priced New York market. With similar developments on the marketing side - e.g. by developing mechanical methods for opening the shells to facilitate removal of the meats and by producing an attractive frozen consumer pack - such carefully controlled industrial scale oyster cultivation has a bright future.

In the undeveloped countries there is considerable interest in and scope for oyster production and it could be an important local source of moderately priced protein if geared to prolific local sources of seed using species suitable to the particular environmental conditions.

As with mussels it is not possible to predict the production of oysters in the future as the potential of oyster culture is very great, but the extent to which it is realised will depend on the economics of new culture techniques and the development of markets at moderate price levels.

Gastropods: 34,000 tons

The carnivorous gastropods (e.g. whelks) are very widely distributed and only very lightly exploited. Factors that militate against their wider use are that they are not particularly favoured as food and are not readily harvested by methods other than baited traps or diving. It seems unlikely that harvesting of this group will expand greatly in the near future, though a study of the ways in which species of this group are prepared and cooked might be merited to see if there is a basis for expanding the demand.

Among the herbivorous gastropods, the abalones and conchs include large species and are much favoured as food. The large scale production of abalones and conchs is not likely to occur due to the difficulties of harvesting by diving on rocky coasts for abalones and by diving and the use of poles for conchs. However there would appear to be considerable scope for more intense harvesting of conchs and the introduction of the larger growing abalones to South America and the North Atlantic where only small species exist.

Table Q2 - Summary of 1966 mollusc production (excluding cephalopods) by major sea areas (catches in '000 of tons, live weight)

	Gastropods	Scallops	Clams	Mussels	Oysters	Various	Total
Northeast Atlantic	6.7	8.5	59.6	222.4	64.4	13.2	368.0
Northwest and Western Central Atlantic	(1.0)	145.6	188.7	(5.4)	300.1	1.0	641.8
Southeast and Eastern Central Atlantic	0.7	-	-	-	0.8	0.1	1.6
Southwest Atlantic	-	0.2	(2.1)	(7.6)	(0.2)	-	10.1
Mediterranean and Black Sea	-	-	-	12.1	-	18.6	20.3
Northeast Pacific	2.2	-	2.7	0.6	59.3	0.1	64.9
West Pacific	18.4	7.4	244.8	4.7	293.1	262.3	830.7
Southeast Pacific	3.5	-	9.7	27.1	0.7	9.9	50.9
Indian Ocean	-	-	-	-	-	2.1	2.1
Southwest Pacific	1.3	13.4	-	(2.4)	(16.5)	(0.9)	34.5
TOTAL	33.8	175.1	500.2	282.9	735.1	308.7	2,035.8

Note - Figures in brackets denote values for 1965, where 1966 values were not available
- means no recorded catches

INTRODUCTION

This section originated in the discussions of the *ad hoc* Working Party on the FAO Indicative World Plan (IWP), Survey of Crustacean Resources, which convened at the FAO World Scientific Conference on the Biology and Culture of Shrimps and Prawns in Mexico City between 12 and 24 June 1967. This Working Party consisted of the following participants, together with observers:

Appolonio, S.
Boschi, E.E.
Broadhead, G.
Butler, T.H.
Cadima, E.L.
Chapa-Saldaña, R.
Chittleborough, R.G.
Ellis, R.W.
Gneri, F.
Hall, D.N.F.
Hancock, D.A.
Holthuis, L.G.
Ivanov, B.
Johnson, D.S.
Kutkuhn, J.H.
Lindner, M.J.
Longhurst, A.R. (Convener)
López, M.T.
Massuti, M.
Obarrio, J.L.
Rasmussen, B.
Simpson, A.C.
Simpson, J.G.
Squires, H.J.
Slack-Smith, R.J.
Tiews, K.F.W.
Weber, D.
Williams, A.B.

The task of the Working Party was to review the first draft of the crustacean document which had been prepared by John Gulland (FAO, Rome) and to accomplish this the Working Party decided to appoint a number of people as Regional Reporters with the responsibility of contacting individuals and organisations within their geographic area in order to obtain current data on the status of stocks of prawns and shrimps on a world-wide basis.

The Regional Reporters were as follows:

I. Northwest Atlantic – Squires, Appolonio
II. Northeast Atlantic – Simpson, A.C.
III. Mediterranean – Massuti
IV.a) Northwest Pacific – Ivanov
b) Northeast Pacific – Butler
V. Western Central Atlantic – Lindner
VI. Eastern Central Atlantic – Longhurst
VII. Western Indian Ocean – Hall
VIII. Eastern Indian Ocean – Hall
IX. Western Central Pacific – Johnson
X. Eastern Central Pacific – Ellis
XI. Southwest Atlantic – Boschi
XII. Southeast Atlantic – Longhurst
XIII. Southwest Pacific – (vacant)
XIV. Southeast Pacific – Hancock

The Regional Reports were all received by the Convener by the end of 1968, and were then consolidated into a reasonably uniform style of presentation to form the basis of the present draft. Only in exceptional cases, and especially with regard to crustacean resources other than shrimps and prawns, was reference made to material other than the reports submitted by the Regional Reporters; the present draft is not intended to be a review of the literature on the subjects covered, and is only as complete as the material submitted by the Regional Reporters. It was originally intended that the survey of crustacean resources should include data on three levels, namely: *present fisheries*; *potential fisheries*, e.g. those areas in which the presence of resources in good quantities is known by exploratory fishing; and *hypothetical fisheries*, e.g. areas in which the depths, type of bottom or other data suggested the existence of quantities of crustacean resources but which have not been confirmed by actual surveys. However, it was evident from the data included in the Regional Reports that this was not a valid division of the material and it was decided to present information at only two levels: that concerning *present fisheries production*, and that concerning the *potential for increased production* in the future; it is necessary here to define the manner in which two terms are used in this paper: *production* may be a rate or an amount and is intended to refer to the catches from a stock of crustacea, and *potential* is intended to refer to the production that may be expected from a stock in the foreseeable future, using fishing techniques which are expected to be available within this period.

An interesting discussion of the whole problem of estimating potential production from present-day data, and in particular from data derived from resource surveys, was received from M.J. Lindner, the Reporter for Region V. His points should be borne in mind when reading the estimates of potential contained in this paper, and it is useful to quote them *in extenso* here.

"At this point it may be useful to discuss methods for estimating potential harvest from areas about which we have limited information. Starting first with an area that has not been fished we might make guesses based on the range of a species or on the size of trawlable fishing grounds. Projections of the fishable magnitude of the stocks of shrimps based on these two methods are subject to such wide error that they are of little or no use. More knowledge than we now have is required to obtain any meaningful projection by these methods. It has been well established that shrimps do not distribute themselves uniformly over vast areas but concentrate in certain localised areas where presumably the temperature, substrata, and food are suitable.

A slightly different situation would prevail if we also had information from exploratory fishing in an area; however, we would still not be in a position to make reliable estimates of potential harvests. Stock estimates of shrimp calculated from exploratory fishing per se approximate only the standing crop or, in other words, only the weight present at any one time. An estimate of the standing crop, consequently, may be highly deceiving if we attempt to use it to estimate the fishable magnitude of the stock, which means the total weight that can be produced from the stock during time intervals such as a year. We are primarily interested in the fishable magnitude of the stock rather than in the standing crop. We need to know how many tons we can harvest safely each year from the stocks. Obviously, we need more information than that provided by exploratory fishing if we desire good estimates of fishable stocks. This additional information may be ecological, involving knowledge of the life history of the feeding and nursery areas of species; it may be based on a comparison of the catch rates or landing data of the same or similar species with those in another area where intensive fishing is in progress; or, it may include the rates of growth, mortality, and recruitment.

Precise measures of stock production must be based on growth, mortality and recruitment rates. These rates however are difficult to get and, indeed, may be impossible to obtain even though the species is heavily fished. The first two approaches, that is, using ecological data or catch data usually do not require the sophisticated methods involved in arriving at rates and frequently a combination of them can give fairly reliable estimates. It seems therefore that we need to start accumulating data on the first two subjects before we can project more accurately than now the fishable magnitude of shrimp stocks in areas that are not heavily fished."

For the reasons outlined above, and from the inconsistent nature of the data available, the estimates of potential production which are contained in this draft cannot be called other than educated guesses; this has been emphasized throughout, and wherever possible a conservative outlook has been taken with regard to estimates of potential production.

The bibliography which conludes this paper has been condensed from the regional bibliographies supplied by the Regional Reporters; it was felt by the Working Party in Mexico City that the value of this document would be greatly increased by the inclusion of comprehensive regional bibliographies, and an attempt has been made to do this for at least some regions.

An attempt has been made to standardize the use of scientific names throughout this draft, but it is certain that some taxonomic confusion is included, especially the reference to a single species by several names, and this was perhaps inevitable from the nature of the material on which the paper is based.

Crustacea are ubiquitous in their occurrence in the sea; they occur in the deepest abyssal benthic communities, in the plankton at all latitudes and all depths of the ocean, and in coastal waters, estuaries and lagoons. Apart from the unicellular animals, marine crustacea are probably, as a group, the most numerous animals on the planet, and they may constitute, as a group, the greatest animal biomass. The following approximate calculations, while not in any sense intended to indicate seriously the production of crustacea of all sorts which might be attained at some time in the future, serve to indicate the magnitude of the crustacean biomass in the oceans. If one considers only the planktonic crustacea, dominated by copepods, sergestids and euphausiids, and if one considers only the plankton of the upper 100 m of the ocean, it is probably near the truth that 100 g of plankton occurs on the average beneath each 10 m^2 of the sea surface. Extrapolating, this gives us 10 tons beneath each km^2 or 3.6×10^9 tons in the upper hundred metres of all the oceans, at any one time. Again, making some slightly dubious assumptions, one may take a value of 80% of this total plankton biomass as being composed of crustacea, and one may conservatively estimate that 50% of the total standing crop at any one time could in theory, be removed by man from the stock over a period of 1 year, providing that natural mortality by other organisms was somewhat under man's control. This gives a potential production of 1.4×10^9 tons annually, or about 30 times greater than the present production of all forms of animal material by the world's fisheries.

The purpose of this estimate is rather to indicate to what extent the presently exploitable crustacean resources are an extremely small part of the total crustacean biomass in the oceans. According to FAO fishery statistics the total world production of crustaceans in 1965 was approximately 1.2×10^6 tons, a figure approximately 1,000 times smaller than the estimate given above.

For the purpose of the present document we are ignoring all crustacean resources which are not likely to be exploited or exploitable within the next decade to any significant extent; because of the extremely tenuous nature of any arguments upon which potential estimates of the euphausiid populations of the ocean must be based, these are not included in the present consideration, even though serious study directed towards the exploitation of one species, Euphausia superba, has been begun in the Antarctic Ocean by the Soviet Union. It is felt at this juncture that the data on the potential from this type of resource are completely inadequate to estimate potential production, and euphausiids and similar stocks are not referred to in the body of this draft.

The biological nature of the crustacean resources which are currently exploited in the ocean is very diverse both as to ecology, and perhaps more important (from a fisheries management point of view) with regard to such biological parameters as rates of growth, mortality and fecundity. Although many of the important crustacean resources occur in warm water, have extremely rapid growth rates, and are virtually annual species, some other important resources, especially those of high latitudes or of deep water, are extremely slow growing and have slow rates of recruitment to the fisheries. The management problems of these two different types of resource are, of course, very different, and too much extrapolation from one type of crustacean resource to all types of resources is to be avoided.

Crustacean resources are also extremely different in the amount of usable meat which is yielded by the processing of various forms; the yield may vary from as low as 8 to 10% in the case of the Chilean langostino to as high as 60 to 70% in some of the fisheries for large penaeid prawns. The figures used in the tabulated data in this text all refer to whole live weight, and to each species should be applied a factor, unknown in most cases, which would translate these into data referring to the usuable meat yield.

The crustacean resources discussed in the following text may be categorized as follows: (1)lobsters, spiny lobsters,and similar forms - Homarus, Nephrops, Palinurus, Panulirus and Jasus;(2) crabs of a number of different forms, king crabs (Paralithodes), Tanner crabs (Chionoecetes),edible or market crabs (Cancer), portunid swimming crabs (Callinectes), and galatheid crabs (Pleuroncodes), etc; and (3) prawns and shrimps, including the high latitude and deep-water pandalids (Pandalus), the low latitude penaeid prawns (Penaeus), the caridean shrimps (Palaemon and Macrobrachium), and finally the deep-water penaeid prawns of low latitudes.

Lobsters and Spiny Lobsters

The true lobsters of the genus Homarus occur on rocky coasts on both sides of the North Atlantic; they are rather slow growing, the females reaching first maturity at 5-8 years (depending on latitude) and the individuals remaining in the fishery for 12 years or more,and occasionally surviving to 25 or 30 years old. The adult females have a 2-year moulting cycle, alternating with spawning years, so that spawning and moulting occur in alternate years. The females carry the fertilized eggs for from 10-11 months before releasing the larvae into the plankton, for the relatively short planktonic life of 4 or 5 larval stages. Evidently, this is a relatively slowly renewing source and in common with all fishery resources in which the individuals which are relatively long lived the fishery is not very productive in the sense that only a small proportion of the total standing crop or biomass may be removed annually on a sustainable basis. Probably for this reason, the lobster stocks are generally approaching an overfishing situation.

The Norway lobsters Nephrops spp. are much smaller organisms which occur on rather deep muddy bottoms in many parts of the world, having been recorded in the North Atlantic, the Indian Ocean and the Northeast Pacific. There are very few biological data on this genus, and as a whole the fishery exploits the stocks only rather lightly.

The spiny lobsters or rock lobsters of the genera Palinurus, Panulirus and Jasus occur in rather lower latitudes than Homarus and species of these genera are ubiquitous in occurrence on hard substrates throughout the warmer parts of the ocean, forming in the tropics a very characteristic component of the reef fauna, though Palinurus appears to be a component especially of rather soft deposits compared with Panulirus and Jasus. Despite this wide distribution, commercial concentrations occur relatively sparsely. Growth rates probably vary widely from species to species, and at least in the tropical oceans members of these genera are probably much faster growing than are the high latitude lobsters of the North Atlantic. Females carry their fertilized eggs and remain in berry for less than two months after the spawning season. The eggs hatch in the spring in latitudes in which the winter has ecological significance, and characteristically pass through a rather large number of planktonic stages. This planktonic phase may occupy periods of almost a year in some species, and this fact is probably of considerable importance when the aquiculture of these genera is being considered, and it may well prove more difficult to rear them commercially, than species of the genus Homarus.

Crabs, King Crabs, etc.

The edible crab, Cancer pagurus, of northern Europe has a biology which is probably typical of generalised crabs which are important in fisheries the world over. In this species, first maturity occurs at a carapace width of about 13 cm, or an age of 4-5 years, and subsequently the females spawn in alternate years. The species performs rather well marked seasonal migrations, occurring inshore during the summer and offshore in deeper water during the winter; during the inshore phase in June to July the eggs carried by the females hatch and the larvae enter the inshore plankton. In the autumn the crabs moult and the large females move offshore where in deep water in December and January spawning occurs, the eggs being carried by the female from then on through an inshore migration in the early spring, in April and May, to be hatched again in shallow water the following year.

The king crab, Paralithodes camtschatica, of the North Pacific is a large anomuran crab (of spider crab form) occurring in water to 250 m deep, -1° to 12°C. It is of rather slow growth, females maturing at a carapace length of 90 mm or at an age of 5-6 years. They spawn in the spring and carry eggs until the following spring when the larvae hatch into four planktonic stages in the months of March to June. The females spawn in shallow water and then return into deeper water, and the pelagic phase has a duration of about two months after which they descend into the benthic community. Female crabs molt annually after the eggs hatch, and just prior to mating. Males molt less frequently as they grow older, only once every three years for big crabs. King crabs live up to 15 years or more. Again, as in the case of the North Atlantic lobster, this is a resource which has rather a slow rate of renewal.

The brachyuran Tanner crab, Chionoecetes spp., which although it is only rather distantly related to the king crab has somewhat similar appearance, also has a somewhat similar ecology; the females mature at a carapace length of 8 cm at a rather advanced age carrying their eggs for 5-7 months and having a relatively short larval period.

The portunid swimming crabs, characterised by the blue crabs of tropical seas (Callinectes) are much more rapidly growing species than those discussed above and although their biology is rather poorly known it is probable that most of the low latitude species are essentially annual, and similar to the tropical prawns discussed below.

Prawns and Shrimps

The prawn resources of high latitudes in both the Pacific and Atlantic Ocean are dominated by pandalids of which the biology of Pandalus jordani in the Northeast Pacific Ocean is typical. This species is a protandric hermaphrodite in which sex reversal regularly occurs. The larvae are pelagic and occur in the coastal plankton, not entering estuaries or lagoons preferentially. At 2-3 years old the juveniles mature into male individuals and in the third or fourth year of life these individuals change into females. There is rather low fecundity from 1.0 to 4.0 x 10^3 eggs per female, which bears one brood of eggs per year at which time a high female mortality occurs. The females carry their eggs over the winter for a 5-month period, and release them into their 3-month pelagic stages in the early spring. The adults die after 2-4 years of life, although in lower latitudes the fishery may include only 2-3-year olds.

Pandalus borealis occurs in the entire boreal and has a very similar biology to Pandalus jordani, but the first male maturity occurs only in the second and third year of life and the females are 4-5 years old. A small percentage of females mature directly at 1.5 years old. Pandalus montagui of the Northeast Atlantic has a rather similar biology and it is certain that most of these pandalids have a relatively high longevity when compared with the shrimp resources of the shallow water and low latitudes. The pandalid resources of high latitudes appear to exhibit submergence towards low latitudes, and throughout the tropics wherever prawn surveys have been carried out on the upper part of the continental slope pandalid resources, more or less abundant, have been found together with a number of deep-living penaeids. The biology of these deep-living pandalids and penaeids is apparently completely unknown.

A number of crangonid shrimps occur in all latitudes and the European shrimp, Crangon crangon, may be taken as a rather typical example, although the lower latitude species of Palaemon and related forms presumably have rather more rapid growth rates and are certainly, in general, annual species. Pelagic larvae of Crangon crangon occur in the plankton from December through August and the adult individuals, unlike the pandalids, are heterosexual although one worker has suggested the occurrence of hermaphroditism in this species. Maturity occurs in the first or second year of life and three broods per year per female appear to be normal. The eggs are carried by the females during the spring to summer months for short periods of 3-4 weeks after which they hatch. Males appear mostly not to survive beyond their second year of life and females beyond their third year.

The resources of penaeid shrimps which occur on continental shelves in low latitudes are heterosexual and the females do not carry the eggs, but these are released into the water as soon as fertilised. The most significant ecological difference between the various species is whether or not the pelagic larvae and post-larvae remain in the coastal, continental shelf plankton or whether they preferentially enter brackish water in estuaries and lagoons, there to pass their juvenile period. Typically, as with *Penaeus duorarum* of the tropical Atlantic, and *Penaeus monodon* and *Penaeus indicus* of the Indo-Pacific, the females have rather long spawning periods throughout the year during which one or more peaks of spawning occur; the number of individual spawnings per female during the course of the season is not known in most cases. Fertilised eggs and early larvae can be found of all these species in the neritic plankton, but the early larvae very rapidly concentrate around lagoons and estuaries and enter on the floodtide. The larvae are at first transparent, and pelagic in the lagoons, but very early settle on the vegetation in shallow water and progressively, as they grow, move into deeper water within the lagoon. Mostly, the larval and juvenile forms spend less than one year in their brackish water environment, at the end of which period they return to the continental shelf where spawning occurs. There are indications in a number of species with this kind of ecology that the life span is only 12-14 months and that the adults die rather soon after returning to the continental shelf and spawning. In this case the large biomass of adults and near adults which are exploited on the continental shelves in the great shrimp fisheries of the world must consist of an ephemeral stock with a very rapid turnover, new individuals being consistently recruited from the nearby estuaries and lagoons.

However, a number of species do not have this ecology; such species occur in regions, such as the Persian Gulf, in which there is little possibility (because of the nature of the geography of the region) for the larvae to enter brackish lagoons, or they may occur alongside species whose larvae regularly and preferentially enter brackish water. Examples of the first kind of species are those which occur, as suggested above, in the northwest part of the Indian Ocean, in the Red Sea, the Persian Gulf and the northern part of the Arabian Sea, where although coastal lagoons and other brackish water environments are extremely limited or absent. Examples of the second sort, in which larvae do not enter estuaries even though these are available for entry are *Parapeneopsis atlantica*, and *Xiphopenaeus kroyeri* of the eastern and western tropical Atlantic respectively, and also *Penaeus latisulcatus* and *Penaeus esculentus* in northern Australia (Frank Alverson, personal communication). In the Gulf of Guinea *Parapeneopsis atlantica* is one of the most abundant inshore species of penaeid, occurring most abundantly on shallow muddy deposits off the mouths of estuaries and lagoons but, unlike its neighbour *Penaeus duorarum* which occurs on similar deposits, its larvae and juveniles are never found in the neighbouring lagoons and estuaries.

REGIONAL ASSESSMENTS

Region I - Northwest Atlantic

This region includes the west coast of Greenland and the Davis Strait, the eastern coast of Canada, and the coast of New England in the USA. Crustacean resources are rather poor in species, and the whole region, with the exception of the southern coast of New England, is influenced by the cold current which passes southwards along the coast of northeastern North America.

A. Lobster resources

This is one of the two centres of production of the Atlantic lobster *Homarus*, which is here represented by *H. americanus*. Landings of this species have varied little in recent years, from an annual rate of about 32.0×10^3 tons:

Country	1961	1962	1963	1964	1965
USA	11.8	12.8	13.2	13.3	13.3
Canada	21.6	21.1	20.0	19.0	18.4

A slight decrease which can be detected since 1962 does not appear to be attributable to any decline in fishing effort and, combined with evidence for a continuing change in population structure (at least off New England) towards a predominance of young individuals, suggests that the stocks are capable of no significantly increased production; indeed, the evidence indicates that only by proper management will the present level be sustained. The consumer demand for this species is extremely high, and with prices rising very significantly industrial tendencies will be towards increasing effort.

In recent years, this species is being taken increasingly towards the south and in recent years has been trawled in deep water as far south as North Carolina (Frank Alverson, personal communication), in Region V, probably in response to a climatic change in the marine environment. What effect this may have in the future is not predictable.

B. Crab resources

A trace of blue crab (*Callinectes* spp.) occurs in the landings in the most southerly parts of the region, but the major crab resources is that of *Cancer irroratus*, the rock crab. In 1966, the US landings of this species amounted to 2.2 x 10^3 tons. This crab occurs in considerable numbers along the eastern coast of Canada as far north as the Strait of Belle Isle (Squires 1966). There are also indications (Wilder 1966), that this species occurs also in deep water off eastern Canada, together with a spider crab (*Chinoecetes*) related to the Tanner crab of the Gulf of Alaska. It would seem altogether possible that a fishery to the extent of 10.0 x 10^3 tons might develop on all these species combined in this region.

C. Prawn resources

The prawns of this region are mostly cold-water pandalids, often occurring in deep water, together with some shallow water palaemonids.

Stocks of *Pandalus montagui*, *Spirontocaris spinus* and *S. lilljeborgii* are known to occur, but their potential is not known, and they are only exploited incidentally to the fishery for *Pandalus borealis*, which is the principal product of the prawn fisheries in the Northwest Atlantic.

While the fishery for *P. borealis* is concentrated mainly off Greenland, in very recent years a start has been made in Canada, where in the Bay of Fundy 0.3 x 10^3 tons were taken in 1967. Resource surveys have proved shrimping grounds, at rates of from 100-800 lb per hour, to the southwest of Newfoundland and in the Gulf of St. Lawrence (Squires 1961). Although no estimates have been made, it is reasonable to assume a total potential in this rather large area of about 5.0 x 10^3 tons eventually.

The potential appears to be about the same off New England, where a minor fishery has existed for decades, but has been subject to remarkable stock fluctuation and therefore in availability to the fishery. The high catches in years of abundance do not properly reflect the relative stock abundance vis-à-vis poor years; when a very strong year-class is recruited to the fishery the market and processing facilities become glutted, and the catch is thus limited.

Year	Massachusetts (tons)	Gulf of Maine (tons x 10^3)
1960	<1.0	-
1961	<1.0	-
1962	16.4	0.1
1963	10.5	0.2
1964	3.1	0.4
1965	8.1	0.9
1966	-	1.7
1967	-	3.0

It seems rather likely that this fishery will in the near future reach a production of 5.0 x 10^3 tons.

Off Greenland, the fishery for *Pandalus borealis* has built up very rapidly in recent years, most of this production coming from Disko Bay and other inshore West Greenland waters to the south. The landings from the Greenland fishery in recent years have been as follows:

1950 - 0.2
1960 - 1.8
1961 - 2.5
1962 - 3.3
1964 - 3.7
1965 - 5.0
1966 - 5.4
1967 - 5.6

Rasmussen suggests that a production of 7.0 to 8.0 x 10^3 will be realised in another decade; the potential of 6.0 x 10^3 tons guessed by Ivanov in 1964 had almost been attained by 1967; and Smidt suggests potential of 12.0 x 10^3 tons, and perhaps more if offshore grounds in the Davis Strait are exploited by big vessels.

D. Total Regional potential

The following tabulation of the estimates suggested above indicates that the total potential of the region may increase by approximately a third in the foreseeable future, reaching a total of 69.0 x 10^3 tons.

	Present	Potential
Homarus americanus	31.7	32.0
Cancer irroratus (and others)	2.2	10.0
Pandalus borealis		
United States	3.0	5.0
Canada	0.3	5.0
Greenland	5.3	12.0
Pandalus montagui	-	5.0
TOTAL	42.5	69.0 (tons x 10^3)

Region II - Northeast Atlantic

The crustacean production in this region is more diverse than in the Northwest Atlantic, to some extent because this region contains a greater degree of ecological diversity, due to the effect of the Gulf Stream on the European coast at high latitudes, but also perhaps due to the longer development of the fisheries in this region in historical terms, because of greater human pressures.

The 1965 catch was partitioned among 12 species, as tabulated below:

Lobsters	
Homarus gammarus	2.3
Palinurus elephas	1.4
Nephrops norvegicus	25.5
Crabs	
Cancer pagurus	7.9
Carcinus maenas	0.7
Portunidae spp.	0.4
Maja squinado	4.7
Prawns	
Pandalus borealis	19.9
Pandalus montagui	0.1
Crangon crangon	45.8
Palaemon serratus	1.8
Parapenaeus longirostris	7.4
TOTAL	117.9 (tons x 10^3)

A. Lobster resources

(1) Common lobster (Homarus gammarus)

Lobsters occur from northern Norway to the Bay of Biscay, and are found on most coastal and near-coastal rocky grounds. Nearly all are national fisheries and over 90% of the yield is believed to be caught within 3 miles of the coast.

Present catch is small, about 2.0 x 10^3 tons, though the value is high. While most stocks are heavily fished there would appear to be scope for 50-70% increases in catches in Norway, United Kingdom and Eire by increased fishing in certain areas, including in deeper water, and better management in others (Thomas 1965). It is considered that there is little prospect of increased yields from Sweden, Germany, Holland or France.

Denmark used to produce over 150 tons per annum, in many years between 1930 and 1950, and it would seem possible that these levels could be achieved again by increased fishing.

The landings of this species, by country, in 1966 are tabulated below, together with an estimate of the resource potential.

Country	1966 landings	Estimated maximum sustainable yield
Norway	0.3	0.8
Sweden	0.1	0.2
Denmark	0.03	0.2
Germany	0.0	0.0
Holland	0.0	0.0
Belgium	0.0	0.0
Scotland	0.6	1.0
England & Wales	0.4	0.6
Eire	0.3	0.5
France	0.4	0.4
Spain	0.0	0.0
Portugal	0.0	0.0
TOTAL	2.1	3.7 (tons x 10^3)

(ii) Spiny lobster (*Palinurus elephas*)

Palinurus elephas is a southern species extending north to Eire, southwest England and the Channel Islands. It lives in very rocky areas with strong tides and occurs from about 10-200 m. It is caught in baited traps, and just recently by full-time SCUBA divers off southwest England.

Country	1965 catch
Eire	0.2
England	0.1
France	0.7
Spain	0.4
Portugal	0.0
TOTAL	1.4 (tons x 10^3)

There is very little information on the population dynamics of the species. Recent work in England and Ireland suggests that the populations there are recruited from further south (pelagic larvae? juvenile migration?) as animals below 2 lb weight are rarely seen, even by divers, and there are substantial long term variations in their abundances. Catches in Eire were of the order of 400 tons annually in the 1950s and 1960s and it is probable that 500 tons is nearer the average long term yield than the present 200 tons. The stock around southwest England is lightly exploited and could probably yield an average of at least 200 tons annually with increased effort. The potential of the French and Spanish grounds is not known but is likely to be somewhat above the present yields. The sustainable yield for the whole area is likely to exceed 2.0 x 10^3 tons.

(iii) Norway lobster (*Nephrops norvegicus*)

Nephrops norvegicus occurs in many areas from Iceland to the Mediterranean where the bottom sediments are a fine mud. Such grounds are typically in water over 120 m but in sheltered areas such as fjords, and where tidal currents are small (Irish Sea), *Nephrops* occur in depths as shallow as 20 m.

A number of new northern grounds have been exploited since 1939 with a steady increase in landings; 10.0×10^3 tons being landed in 1948 and 30.0×10^3 tons in 1964. It would seem probable that there are still some extensive populations which have not been exploited, especially at considerable distances from ports.

The habit of *Nephrops* to form burrows in the bottom and to remain in them at night (and also during full daylight in shallow waters) reduces the efficiency of capture and makes overfishing more difficult. There is little indication that many grounds are very heavily exploited, though recent declines in yield off Norway may be due to this. A decline in average size on some grounds off Scotland is probably due to fishing (Thomas 1965), but considerable increases in fishing effort off Iceland (Sigurdsson 1965) and continued heavy fishing in the Irish Sea (O'Riordon 1965, Gibson 1965) have not lead to decreases in average size of *Nephrops* in the catches in these areas.

The occurrence of *Nephrops* in the stomachs of cod over a wide area northeast of Scotland suggests that landings by Scottish boats from the North Sea could be about doubled to $5.0 \times 10.0 \times 10^3$ tons per annum (Thomas, personal communication). It is also probable that landings from grounds around Ireland could be more than doubled (Gibson, personal communication).

While the stocks south of Norway may not be able to give a much greater yield it would seem probable that the sustainable yield from the Northeast Atlantic area as a whole could be about doubled to around 60.0×10^3 tons. However, it is possible that the most distant fishing grounds will not readily be fully exploited, as the larger boats may find it more profitable to catch fish than Norway lobsters.

The 1965 landings, by country, and the degree of exploitation are tabulated below:

Country	Area	Degree of exploitation	1965 production
Iceland	Near seas	Moderate	3.7
Faeroes	Coastal areas	Light	0.1
Norway	Coastal areas	Light	0.2
Sweden	Kattegat	Heavy	0.3
	North Sea	Moderate	0.0
Denmark	Kattegat	Heavy	0.8
	Skagerak	Moderate	0.3
	North Sea	Moderate	0.0
Germany	Kattegat	Heavy	0.1
Holland	North Sea (by-catch)		0.0
Belgium	South North Sea		0.5
Scotland	North Sea (near seas)	Moderate	3.5
	West coast	Light to moderate	3.0
England and Wales	North Sea (near seas)	Moderate	0.4
Northern Ireland	Irish Sea	Moderate	0.9
Eire	Irish Sea	Moderate	1.0
	Celtic Sea	Light	0.0
France		Moderate	7.4
Spain	Near seas	Moderate	3.8
Portugal	Near seas	Light	0.2
TOTAL			26.4 (tons x 10^3)

B. Crab resources

(i) Edible crab (*Cancer pagurus*)

This crab is common where there is a rocky coastline, though, due to seasonal offshore migrations, considerable quantities of crabs are also to be found up to 10 mi offshore and into depths of 80 m on soft ground. Crabs are nearly all caught by baited traps, though some are caught as an incidental catch by trawlers.

Crabs are low-priced and therefore long-distance transport to markets is usually not economic. Recent developments have been towards regional processing plants, leading to deep-freezing and canning, which has stabilised fisheries and allowed their expansion away from major consuming centres. This process is progressing in several countries. The most heavily exploited stocks are on the British coast, but recent investigations show that the fishery is now taking about the maximum sustainable yield (Edwards 1967).

Country	1965 landings	Estimated maximum sustainable yield
Norway	3.4	5.0
Sweden	0.2	0.4
Denmark	0.0	0.1
Germany	0.0	0.0
Holland	0.0	0.0
Scotland	1.8	3.3
England and Wales	2.6	3.5
Eire	0.1	0.5
France		0.5
Portugal	0.1	0.1
Spain	0.1	0.1
TOTAL	8.3	13.5 (tons x 10^3)

It is possible that yields from Norway could be substantially increased as the average size of crabs caught there is large.

The maximum sustainable yield from the region is probably between 50 and 100% above the current yield of 8.0 x 10^3 tons, and a potential of 13.5 x 10^3 tons is assumed for our present purpose.

(ii) Shore crab (*Carcinus maenas*)

This crab is very abundant in coastal waters in the central and southern part of the area, being killed in shallow waters in the North Sea in severe winters. It is only exploited commercially in Spain and Portugal where a total of some 0.3 x 10^3 tons per annum are landed.

As it is a major predator on the young of a commercial species of mollusc, the development of a fishery for this species could benefit mollusc production. There is also a demand for "peeler" crabs of this species in Italy.

(iii) Spider crab (*Maja squinado*)

This species is common in the southern part of the area to the coast of Ireland and the Western English Channel and occurs also in the Mediterranean. At certain times of the year it aggregates (as does the Tanner crab in the North Pacific) into what are believed to be spawning piles, when large numbers can be caught by trawling. At other times they are usually caught by trapping. The meat yield is low during much of that year but the muscle tissue is sweet, and highly esteemed.

The present fishery is limited to France, Spain, Yugoslavia and Portugal and very small quantities in southern England, and separate landing statistics are only kept for Portugal. Present landings are 4.7 x 10^3 tons; this figure could probably be increased to about 6.0 x 10^3 tons.

(iv) Swimming crab (Portunidae spp.)

These crabs are common throughout most of the area but are only exploited by Spain. Potential yields are unknown.

C. Shrimp and prawn resources

(i) Pandalus borealis

This cold water (3-8°C) species occurs from north of Spitsbergen to the northern North Sea on clay and mud bottoms. It rarely occurs in quantity in water less than 60 m deep but extends to depths greater than 1,000 m. However, present day fisheries are limited to depths between 60 and 600 m.

1965-1966 landings by countries

Country	Iceland	Norway	Sweden	Denmark	Total	Potential
Iceland	1.4				1.4	2.0
Faeroes					-	1.0
North Norway		4.4			4.4	6.0
Northwest		0.6			0.6	2.5
West		1.9[1/]			1.9	2.0
South (Skagerak)		1.8[2/]	1.5[3/]	0.9[4/]	5.1[5/]	12.0
Kattegat				0.8	0.8	1.0
N. Sea Fladen				3.0	3.0	4.0
Farne Deep						1.0
TOTAL	1.4	8.7	1.5	5.6	17.2	31.5 (tons x 10^3)

Notes - 1/ 3.5×10^3 tons per annum in 1960-64
2/ 3.2×10^3 tons per annum in 1960-64
3/ 5.0×10^3 tons per annum in 1962
4/ 2.0×10^3 tons per annum in 1962-64
5/ 10.2×10^3 tons per annum in 1962

Around Iceland the development of Pandalus fisheries has been only during the past decade and new grounds are still being found.

Present production is around 1.4×10^3 tons. This could be somewhat increased by reduced fishing in the most heavily fished areas (Skuladottir 1967) and extended new fisheries, giving a yield which might be somewhere about 2.0×10^3 tons.

There is no fishery for Pandalus at Faroe. There is no information on the occurrence of Pandalus in this area but from temperatures, depths and bottom types, useful populations can be anticipated.

Fishery for Pandalus off Norway started in 1897 following research by Johan Hjort. The fishery has continued to expand and 1,500 Norwegian trawlers of 30-80 ft now work the whole length of the Norwegian coast and offshore grounds down to 600 m, wherever the ground is of soft clay and mud. There is no evidence of overfishing but a minimum mesh of 30 mm throughout the trawl is in force to minimise destruction of young prawns (Rasmussen 1967).

In that part of the Norwegian Deep which extends along the south coast of Norway, Denmark and Sweden, with mean annual yields in 1965 and 1966 of 1.8, 1.8, and 1.5 tons x 10^3 respectively.

Five-year means of landings from off the Norwegian coast since 1950 were as follows:

	1950-54	1955-59	1960-64	1965-66
North	1.0	2.0	3.2	4.4
Northwest	0.3	0.3	0.4	0.6
West	0.7	2.0	3.4	1.9
South				
a) Norway	1.3	1.9	3.3	1.8
b) Denmark	?	?	4.5	1.8
c) Sweden	?	?	4.5	1.8 (tons x 10^3)

There appears to be some scope for further development, especially in northern Norway, and a mean total annual yield of about 20.0 x 10^3 tons is probably attainable without working into deeper water. The catches fluctuate partly as a result of variable year-class strength and partly from changes in water temperature, which can make the prawns leave the normal fishing grounds temporarily (Rasmussen 1967). Catches were down off West and South Norway in 1965 and 1966, but the maximum sustainable yield is probably slightly above the 1960-64 average 10.0 x 10^3 tons.

The Kattegat is only fished by Danish boats, which produce 0.2 to 0.8 x 10^3 tons a year. There seems little chance of raising this much above 1.0 x 10^3 tons as the grounds are all known and heavily fished.

Since 1960 Danish boats have been fishing the Fladen grounds of the North Sea and yields have been around 3.0 x 10^3 tons a year in 1965 and 1966. In 1967, German and Danish trawlers have started fishing the Farne grounds 15 mi from the coast of England but yields are not known.

(ii) Common or brown shrimp (Crangon crangon)

Total landings of shrimps for food and industrial uses from Germany and Holland have fluctuated between 4.0 and 70.0 x 10^3 tons in recent years. Increases in the size and efficiency of the Dutch fleet have been compensated by a reduction in the German fleet.

Crangon crangon is limited to estuarine and coastal waters between the Central North Sea and the Bay of B
Germany and Holland where extensive shallow sandy areas form its main habitat.

There is a substantial fishery in both countries for small shrimps for meal. Some increase in the weight of shrimps for human consumption can be expected by the use of larger meshes in the shrimp nets which would increase the efficiency of capture of the large shrimps as well as releasing small shrimps to be recaptured at a larger size.

At present Denmark does not permit fishing for shrimps within the 3 mi limit though the resources here could probably yield 1.0 x 10^3 tons per annum.

Dutch catches for human consumption could probably be increased by 50% by greater efficiency and the protection of small shrimps.

Catches by England in The Wash and in the Thames estuary could probably be increased to 1.0 x 10^3 tons by greater efficiency. The future of the Irish Sea fishery is uncertain due to the possible construction of a barrage across Morecambe Bay - the main shrimp fishing area - but annual catches from the whole of the Irish Sea could probably be maintained around 0.7 x 10^3 tons.

French catches have been increasing steadily in recent years

1960 - 1.4	1965 - 2.0
1962 - 1.8	1966 - 2.3 (tons x 10^3

and it is probable that the sustainable yield is around the 1.5 x 10^3 tons for the Channel and 2.5 x 10^3 tons for the Atlantic coast, if not more.

The following tabulation summarises present and potential production of this species:

Coastal waters of	1966 production	Potential yield from known grounds
Denmark	-	1.0
Germany	27.3 1/	28.0
Holland	14.7 2/	15.0
Belgium	1.0	1.0
Scotland	0.1	0.1
England N. Sea	0.8	1.0
Irish Sea	0.5	0.7
France		
English Channel	0.9	1.0
Atlantic	1.4	1.5
TOTAL	46.7	49.3

Notes - 1/ Includes 21.6 x 10^3 tons small shrimps for industrial use

2/ Includes 6.5 x 10^3 tons small shrimps for industrial use

(iii) Pink shrimp (Pandalus montagui)

This species extends from the English Channel to the Arctic and is found on harder bottom in estuaries and into deeper waters. It does not grow to a large size, rarely exceeding the size of the brown shrimp, the larger shrimps having a count of around 400 to the kilogramme.

At present it is only fished commercially by Britain where catches during the past decade have been only a few tens of tons compared with hundreds of tons prior to 1958. The reduced catches have been due to a general scarcity of the species on the three main fishing grounds - The Wash, Thames estuary and Morecombe Bay due to causes unknown.

No attempts have been made to find fishable concentrations in other countries, but it is probable that such concentrations exist, especially around Scotland, Norway, Faroes, and Iceland, where it is known to be present. But, being a small species, requiring picking by hand, it is uncertain whether fisheries would develop even if substantial concentrations were found.

(iv) Dichelopandalus bonnieri

This prawn is present in quantities which could probably support a fishery in various localities on the West of Scotland and probably elsewhere.

No fishery exists at present and it is impossible without more information to assess its potentialities.

(v) Palaemon adspersus

This prawn is only fished commercially in the Baltic by Denmark where catches have varied between 60 and 340 tons in the last 5 years.

While this prawn also occurs in many areas it is unlikely to be able to support substantial fisheries anywhere.

(vi) Crevette rosé (Palaemon serratus)

Palaemon serratus is one of the larger palaemonid prawn reaching counts of 100 per kg. It is a southern species, the most northerly fisheries being in the English Channel and Wales where cold winters cause substantial mortalities. It lives among sea weeds on rocky coasts and on the adjacent sea bed being caught both by baited traps among the algae and by trawls. Yields are not likely to be great anywhere, but it is at present the subject for artificial rearing (MAFF, Conway, and commercial enterprise in England) which if successful could give substantial production.

Production in 1966 was as follows:

English Channel	<10 tons (Potential 10-100)
French Atlantic coast	700 tons (Potential 1.0 x 10^3 tons)

D. Total resource potential of Region II

The following tabulation synthesises the various estimates and potentials discussed above. The rather surprising high potential increase in production rates which are suggested by these figures probably reflect rather the state of exploration of the region rather than that it is inherently rich in crustacean products. Such observations may be held to indicate that estimates made in rather poorly explored regions may very well be too low.

	Present	Potential
Lobsters		
Homarus vulgaris	2.1	3.3
Palinurus vulgaris	1.4	2.0
Nephrops norvegicus	26.4	60.0
	(29.9)	(65.3)
Crabs		
Cancer pagurus	8.2	13.5
Carcinus maenas	?	?
Maia squinado	4.7	6.0
Portunus spp.	0.4	1.0
	(13.3)	(20.5)
Prawns, etc.		
Pandalus borealis	17.2	31.0
Crangon crangon	46.6	49.3
Pandalus montagui	0.1	0.1(?)
Dichelopandalus bonnieri	?	?
Palaemon adspersus	<0.5	0.5
Palaemon serratus	<1.0	1.0
	(65.4)	(82.8)
TOTAL	108.6	168.6 (tons x 10^3)

Region III - Mediterranean and Black Sea

These inland basins are rather unproductive of crustacea and the extremely oligotrophic nature of their ecology suggests that their potential production relative to other sea areas is likely to be low; nevertheless, the 25.0 to 30.0 x 10^3 tons of crustacea produced each year from this region is surprisingly high, yet this is probably only a reflection of the relatively highly - exploited nature of the resources. As for fish, so for crustacea; the fishing pressure is probably extremely high relative to the low production rates of the marine resources as a whole in these seas.

The production statistics are extremely variable in their quality, and to obtain any overall estimate of present day and hypothetical production one must make many assumptions, perhaps more than in some other regions.

A. Lobster resources

(i) European lobster (*Homarus gammarus*)

There is a very small production of this species, scarcely exceeding 1.0 x 10^3 tons annually, in the Mediterranean Sea, mostly taken by Italian boats, although this apparent national preponderance may very well be due to anomalies in the reporting methods of production statistics from various countries.

(ii) Norway lobster (*Nephrops norvegicus*)

This species appears to occur rather widely in deep water in the Mediterranean Sea and production is considerably higher than for the European lobster. Again, however, the main producing country appears to be Italy with Algeria, Spain, and Yugoslavia each adding rather smaller quantities to the total. The total production from the Mediterranean has remained extremely constant for the last decade, varying only between 2.0 and 3.0 x 10^3 tons annually.

(iii) Spiny lobster, rock lobster (*Palinurus elephas*) - - *P. vulgaris*

An extremely small quantity almost always less than 1.0×10^3 tons annually, of this species, together with traces of *P. regius* (green rock lobster) are taken in the Mediterranean Sea annually. The catches are produced mostly by vessels from Algeria, France, Italy, and Spain although it is extremely likely that small quantities are taken by a number of other countries, but do not show in their fisheries statistics.

B. Crab resources

Extremely small quantities of various species of crabs are taken in the Mediterranean basin, appearing in the statistics of France, Spain, and of Yugoslavia. The total has never been recorded as exceeding 1.0×10^3 tons annually and little expansion appears to be possible.

C. Prawn and shrimp resources

The bulk of the production of crustacea in the Mediterranean Sea is included in this resource category, the production of which has been rising slowly but rather steadily in recent years. From less than 20.0×10^3 tons a decade ago the production is now approaching 25.0×10^3 tons. This figure does not include shrimps and prawns which may be included in the statistical category "various marine crustacean" as reported by a number of countries, the total of which for the Mediterranean and the Black Sea basins is now approaching 10.0×10^3 tons. It is to be expected that 50-75% of this total should be applied to production from the prawn and shrimp resources. The production statistics from most countries do not permit partition of the total production among the constituent species, and it is difficult to apportion relative importance to the species which are known to occur in the Mediterranean and Black Sea catches, and which are tabulated below.

Prawns and shrimps of economic importance in the Mediterranean and Black Seas; scientific and Spanish names

Gamba	
Parapenaeus longirostris	Gamba blanca
Solenocera membranacea	
Crangon crangon	
Gamba de Profundidad	
Aristeomorpha foliacea	Gamba roja
Aristeus antennatus	Gamba rosada (*Gambli rossi* - Malt.)
Plesionika edwardsii	Carabinero
Langostino	
Penaeus kerathurus	Langostino
Quisquilla	
Palaemon elegans(=*L. squilla*)	
Palaemon xiphias	
Palaemon adspersus	
(*Plesionika* spp. ?)	

Of the species tabulated above, *Parapenaeus longirostris* is probably the species of which the greatest catch is taken currently in the Mediterranean, and this is certainly true for those countries such as Spain, France, and Italy for which the statistical data are relatively sophisticated. Probably next in importance are the deep-living prawns (known in the Spanish fishery as gamba de profundidad) and it is probably this resource from which the greatest increase of production may be expected, although it is already rather well surveyed and is already under fairly heavy exploitation, particularly in the western basin of the Mediterranean from Italy and Sicily to the Straits of Gibraltar; *Aristeus antennatus* is the only commercial shrimp taken at Malta, where it occurs at 200-400 m on soft clayey deposits. These Central Mediterranean grounds already appear to have reached their maximum production (J.A. Galea personal communication). While both gamba and gamba de produndidad are known to be dominant in the landings of Spain, France, Italy, Tunisia, and Algeria, the langostino, *Penaeus kerathurus* (which is a penaeid of exceptionally large size, and which occurs also along the tropical West African coast) is important in some of the smaller fisheries because of the relatively high value of the individual prawns on the market.

The small shrimps of the genera Crangon and Palaemon are nowhere taken in large quantities; the largest production which is probably attributable to such forms appears to be that reported by Bulgaria where it has reached between 4.0 and 5.0 x 10^3 tons annually.

In the Central Mediterranean the only shrimp fishing in the Adriatic is beyond 600 m depth, while in the Ionian Sea coastal fishing predominates; in the remainder of the region (Tyrrhenian and Ligurian Seas, and around Sardinia and Sicily) shrimp trawling occurs from the coast out to 600 m. It seems, from the rather dispersed statistics available that Italian catches (1967 - 10.0 x 10^3 tons) dominate, and make up a large part of the total Mediterranean shrimp catches.

In the eastern Mediterranean, shrimp production occurs in only a few areas (Ivanov 1964) notably on both east and west coasts of Greece along the Turkish seaboard, on the coast of Israel, and off the Nile Delta.

The Greek production is based on Penaeus kerathurus, which forms 50% of the catch, together with Parapenaeus longirostris and Palaemon elegans. Catches are consumed fresh and locally and amount to almost 0.5 x 10^3 tons annually. The Turkish production amounts to about the same figure annually and probably depends upon the same species.

The Turkish shrimp production extends from the Sea of Marmora (where no trawling, only traps, is permitted) to Adana in the east. The major exploited species are Parapenaeus longirostris, Penaeus trisulcatus, P. semisulcatus, and Metapenaeus monoceros, the last two of these being Indo-Pacific species which have migrated through the Suez Canal. Total production is less than 0.5 x 10^3 tons and no data are available regarding specific composition of the catches. Until recently, Iskanderun Bay at the eastern end of the coast was a major centre of production, but has now been fished out and the commercial fishery there has collapsed.

The Egyptian production is rather greater, and in 1957 the catches off the Mediterranean coast were about 2.8 x 10^3 tons. In recent years (if one accepts Hall's estimate that 50% of UAR production comes from the Indo-Pacific, see p. 28) the production has been about 5.0 x 10^3 tons. It is not known what species are represented in the catches. The effect of the Aswan High Dam will probably be to reduce production from this fishery.

D. Total resource potential of Region III

It is extremely difficult to estimate in an objective fashion the potential production in this region but it seems, from the stability of the landings, and from the general interest in the European markets in crustacea, that the relative level of exploitation is probably already rather high of fisheries as disparate as those in deep water around Malta and in shallow water in Iskanderun Bay, so that no great increase can be expected. As indicated earlier, any major increase will probably come from the deeper-living shrimps and prawns which, although their general distribution is now fairly well understood have only in recent years come under heavy exploitation.

Because of these facts it is not postulated that the landings could be expected to increase in the foreseeable future beyond 50.0 x 10^3 tons altogether and this estimate may in fact be generous, but is a conveniently rounded number, to be used here as the potential. In fact, it represents a little more than a 20% increase on present production, and an increase of this magnitude may be quite realistic.

Production of crustaceans in recent years and future potential
Mediterranean and Black Sea

	1958	1961	1962	1963	1964	1965	Potential
Prawns, etc.							
Crangon crangon	1.0	+	+	+	+	+	
Others	19.0	21.0	21.0	21.0	22.0	23.0	
Lobsters							
Homarus gammarus	1.0	1.0	1.0	1.0	3.0	1.0	
Nephrops norvegicus	3.0	3.0	2.0	2.0	2.0	3.0	
Palinurus elephas	+	+	+	+	1.0	+	
Crabs							
Miscellaneous crabs	+	+	+	+	+	+	
Various crustaceans (Taxa not stated)	4.0	7.0	9.0	8.0	9.0	9.0	
TOTAL	28.0	32.0	33.0	32.0	37.0	36.0	50.0 (tons x 10^3)

Region IV - North Pacific

This region encompasses the whole of the North Pacific from the cold waters north of Hokkaido to the California Current at the level of the Mexican border. Here the important members of the crustacean fauna are quite different from the crustacea of the warmer parts of the Pacific - pandalid shrimp replace penaeids, various spider crabs replace spiny lobsters, and swimming crabs are virtually absent.

A. Crab resources

The king crab (*Paralithodes camtschatica*) has been for many years the most valuable single-species crustacean fishery in the region, being taken by fleets from USA, USSR, Japan and Korea. The total landings of this species have shown the following development:

1938 - 79
1948 - 18
1958 - 66
1961 - 88
1962 - 103
1963 - 112
1964 - 120
1965 - 132
1966 - >149.5
1967 - >133.9 (tons x 10^3)

The centres of production of king crabs have been: the Okhotsk Sea (and Tartar Strait, W. Sakhalin and N. Hokkaido); the Bering Sea; the Gulf of Alaska, especially near Kodiak. Traditionally, the US fleets have fished the Gulf of Alaska and some parts of the Bering Sea, while the USSR and Japanese fleets have occupied themselves with the stocks in the Okhotsk and Bering Seas; the division of the catch among the various fleets in some recent years was as follows:

Country	1963	1964	1965	1966	1967
Japan	31.6	31.8	25.9	31.0	30.0
Korea	2.3	2.2	4.7	-	-
USA	35.7	39.3	51.2	72.5	61.6
USSR	42.5	46.2	44.2	46.0	42.3
TOTAL	112	120	132	>149.5	>133.9 (tons x 10^3)

There have been indications that the stocks in the Okhotsk Sea to the west of Kamchatka have seriously declined in recent years and it is unlikely that the potential production is greater than the present figure of 40.0-45.0 x 10^3 tons together with less than 5.0 x 10^3 tons of blue king crab (*P. platypus*); this fact, is however, not demonstrated in the catch statistics because the Soviet and Japanese fleets turned their effort elsewhere. A decline, which may be the result of the year-class fluctuation or may be due to overfishing, is now becoming evident in the data from the Gulf of Alaska. In the early 1960s, before any decline in availability became evident, the approximate distribution of the catch was as follows:

Okhotsk Sea	- USSR	31.1
	Japan	11.1
Bering Sea	- USSR	9.0
	Japan	13.5-18.0
	USA	+
Gulf of Alaska	- USA	59.4 (tons x 10^3)

The evidence for a decline in king crab availability has turned attention towards the Tanner crabs of the genus *Chionoecetes*. Three species are important in the North Pacific, and there is some evidence that their abundance may be linked to that of the king crab (Alverson personal communication), so that their availability has increased as the stocks of king crabs have decreased: *C. tanneri* occurs commonly in deep water from California to Washington, while *C. opilio* and *C. bairdi* occur in shallower water in the Gulf of Alaska. Species of this genus form about half the Japanese crab landings, and are exported under the name of "snow crab".

Also occurring in the region is the Dungeness crab, *Cancer magister*, of the western seaboard of North America, together with similar species on the Asiatic coast. The landings on the American coast follow, but similar data for the Asiatic coast are not available:

Country	1963	1964	1965	1966	1967
USA	11.3	10.5	12.2	18.1	17.7
Canada	1.5	2.0	1.6	2.1	2.4

The crabs *Lithodes aequishina* and *Geryon quinquedens* are also available and may have some potential in the region, though they are deep water crabs occurring at 300-1,000 m and may require the development of special techniques for its exploitation. A Japanese trap fishery at 300-500 m mainly now produces about 3.0 x 10^3 tons per year of *L. aequidens*. Other species of crabs that could be commercially valuable are *Erimacrus isenbeckii*, *Telmessus cheiragonus*, and *Paralithodes brevipes*.

The recent decline in the availability of king crab suggests that the total potential of this resource may not be as high, on a sustained basis, as the highest annual catch rates recorded in the data. For this reason, a very conservative potential production of 100.0 x 10^3 tons annually is used here. The potential production of the Tanner crab is harder to guess. It has been suggested that it may be as high as that of the king crab, but if there is ecological competition between these species their potential productions should be considered together. For this reason, the yield of Tanner crabs is guessed at being half that of king crabs when both are being exploited and a combined figure of 150.0 x 10^3 tons for the two species is postulated.

The potential production from the Dungeness crab stocks is hard to estimate; the annual fluctuations in availability seem to be due to year-class fluctuations, and there seems to be no evidence of serious over-exploitation. An increase x 2 over present average production of 22.0 x 10^3 tons is postulated for present purposes. It is assumed, also, that a same potential of *C. amphioetus* occurs on the Asiatic coast, though it is concealed in FAO production data, and a total potential of 50.0 x 10^3 tons for the whole region is used here.

B. Prawn resources

The prawn and shrimp resources of the region are dominated by about six species of pandalid prawn and a small number of crangonid shrimps, of much lesser importance.

On the Asiatic coast, the pandalid catch off South Korea amounted to about 3.2 x 10^3 tons in 1965, and was dominated by *Pandalus hypsinotus*; the North Korean catch, in which this species, together with some *Pandalus latirostris*, is again dominant, probably raises the total Korean catches to about 5.0 x 10^3 tons. In the Okhotsk Sea the pandalid resources are known to be rich, but production has not yet begun. Here, *Pandalus goniurus* dominates, except along the west coast of Kamchatka, where *P. borealis* becomes important. The potential of this area is not known, but is guessed to be at least

10.0 x 10^3 tons annually.

The production statistics for the Bering Sea and the Gulf of Alaska are combined, and the composition of the catches are as follows: *Pandalus borealis* (80-90%), *Pandalopsis dispar* (5-15%), *Pandalus goniurus*, *P. hypsinotus* and *P. platyceros* (<5%). Annual catches for the whole of this area were:

Year	USA	USSR	Japan	Total
1961	7.3		10.2	17.5
1962	7.7		18.0	25.7
1963	6.9		31.6	38.5
1964	3.5	0.6	20.9	25.0
1965	7.6	2.7	9.8	20.1
1966	10.9	10.7	2.9	24.5 (tons x 10^3)
1967	-	14.3	3.3	-

Especially in the Bering Sea, the bulk of the landings until the last few years had been made by the Japanese fleet, which has achieved a maximum production of around 30.0 x 10^3 tons. The resources are concentrated in a number of locations, among them the Pribiloff Islands in the Bering Sea. Here a Japanese fleet achieved the following production figures:

1961 - 10.2
1962 - 21.0
1963 - 31.6
1964 - 20.9
1965 - 8.8
1966 - 2.9 (tons x 10^3)

This catastrophic collapse was probably due to gross overfishing, and the fleet has recently left these grounds, and turned its attention to the stocks of *P. goniurus* in the Aradyr Gulf.

There are extensive (but mostly unmeasured) areas in Alaskan coastal waters where shrimp fisheries may develop in the future. No reliable prediction of potential production is available. Now, fisheries are located on shrimp stocks with very high concentrations and/or close proximity to ports. As demand grows, operations will undoubtedly expand into more distant areas having lower shrimp densities. Among the potential shrimp areas are southeast Alaska and the Aleutian region. About 17,500 km^2 of ground near the Shumigan Islands can also be considered a potential shrimp area since the Soviet fishery there is now restricted to the offshore zone by US closure to foreign fishing of the 12-mi zone. Dominant species in unexploited areas are expected to be *Pandalus borealis* and *Pandalopsis dispar*.

It is probably a reasonable supposition that when all latent resources in this area (Bering Sea-Alaska) are in production the catches will be at least double the present figure. This is used for present purposes, and the total potential production is assumed to be about 100.0 x 10^3 tons per year.

Off Canada, the present trap and trawl fisheries are supported by: *Pandalus jordani*, *P. borealis*, *P. platyceros*, *P. hypsinotus*, *P. danae* and *Pandalopsis dispar*. Recent years' catches follow:

1961 - 0.5
1962 - 0.7
1963 - 0.8
1964 - 0.5
1965 - 0.8
1966 - 0.8 (tons x 10^3)

Only the area of shrimp trawling grounds is known with any certainty, the total area trawled now and in the past being about 180 km^2. The area of trap grounds for *P. platyceros* appears to be considerably less. The prevailing rate of exploitation is high on trawling grounds near Vancouver and around Vancouver Island, for *P. borealis* and *P. jordani*, and greater effort there will not increase catches appreciably. Stocks of *P. platyceros* available for trapping are believed to be utilised at a low level.

Exploratory fishing between 1953 and 1967 has revealed unexploited grounds for *Pandalus borealis*, *P. jordani*, *P. platyceros*, and *Pandalopsis dispar*. Catch rates, using 70-ft semi-baloon Gulf, and 36-ft shrimp otter trawls, were from 20-380 kg per hour in inlets and 50-600 kg per hour on the outer coast. An estimate of potential trawling area is 630 km^2, and virtually all suitable shrimp trawling grounds have been explored, they are not now under exploitation. On the other hand, probably more than half the British Columbia coast remains to be explored by traps. Consideration of the known potential and hypothetically fishable grounds leads one to anticipate that production will increase by 450 tons within 10 years, giving a total production potential of about 12.0 x 10^3 tons annually.

On the open Washington coast *Pandalus jordani* supports a trawl fishery. The present annual catch is variable, ranging from nil to 2.5 x 10^3 tons annually, and about 0.4 x 10^3 tons were landed in 1967. The size of the fishery is determined by the strength of the dominant year-class, and it is believed that production is near the maximum sustainable yield. In years of high availability, boats which normally trawl for bottom fish convert to shrimp trawling.

No potential or hypothetical fishery off Washington is known.

Species under exploitation in Puget Sound include *Pandalus jordani*, *P. borealis*, *P. platyceros*, and *P. danae*. Annual catches for the area, including Hood Canal, in 1965 and 1966 were 28 and 22 tons, respectively. A breakdown of the 1967 commercial catch showed that traps took 8.3 tons and beam trawls 3 tons. Also in 1967 the catch of the sport trap fishery for *P. platyceros*, *P. danae*, and possibly *P. jordani*, was estimated at 8.6 tons. Stocks are presently being fished to near their maximum potential.

The potential production of *P. jordani* and *P. borealis* in South Puget Sound and Hood Canal, from about 400 km^2, is estimated at about 2.5 tons. Undoubtedly there are small isolated populations of shrimp scattered throughout Puget Sound which are not now being fished. The total potential for Washington is less than 3.0 x 10^3 tons annually.

The only species currently subjected to trawling off Oregon is *Pandalus jordani*. Production averaged 1.1 x 10^3 tons for the 10-year period ending in 1966, and a record of 4.7 x 10^3 tons was reached in 1967. Recent surveys of Oregon shrimp grounds have shown stocks to be abundant in most areas. Population size is known to vary from year to year, yet it appears that the exploitation rate is at a level somewhat below the optimum. Thus, an increase in production may be expected and it is anticipated that the catch will double within 10 years.

No potential shrimp trawl fisheries are known, or anticipated, off Oregon. Of a hypothetical nature is a trap fishery for *Pandalus platyceros* on the rocky bottom of Hecete Bank, Stonewall Bank, and Astoria Canyon, consisting of at least 450 km^2. This type of bottom appears similar to that elsewhere where *P. platyceros* is fished.

A total production potential of 10.0 x 10^3 tons may, therefore, be assumed for Oregon.

Shrimps being fished at present on the California coast are *Pandalus jordani* and *P. platyceros*. Trawl catches of the former species in recent years were:

1962 - 0.8
1963 - 0.9
1964 - 0.4
1965 - 0.6
1966 - 0.5
1967 - 0.6 (tons x 10^3)

P. platyceros catches from a trap fishery are negligible, not reaching tens of tons in recent years.

Other minor fisheries for three species of *Crangon* exist in San Francisco Bay, and a potential exists for development of a small trawl fishery for *Sicyonia ingentis* off Santa Barbara.

It is unlikely that the total California potential production will be greater than 2.0 x 10^3 tons annually, even with all minor potential species in production.

C. Spiny lobster resources

A very small fishery, landing about 250 tons annually, occurs for *Panulirus interruptus* off Southern California. This is fully exploited and is neglibible in the present context.

D. Total production potential of Region IV

Table N indicates the conservative estimates of potential production of crustacea from Region IV that have been used in the above discussions. This may very well be considerably too low, but there do not appear to be good reasons from presently available data to set it higher.

	Present	Potential
Crabs		
Paralithodes camtschatica	150.0	100.0
Chionoecetes spp.	<38.0	100.0
Cancer magister	≈20.0	50.0
	(208.0)	(250.0)
Prawns		
Pandalus spp.		
Korea	5.0	5.0
Okhotsk Sea	?	10.0
Bering Sea and Gulf of Alaska	26.9	100.0
Canada	0.8	1.2
U.S.A.	8.4	15.0
	(41.1)	(131.2)
TOTAL	249.1	381.2 (tons x 10^3)

Region V - Western Central Atlantic

This region comprises the Atlantic coast of the United States, the Gulf of Mexico, the Antilles and the Caribbean Sea, and south along the east coast of South America to the eastern boundary of Venezuela. This is an oceanographically complex region, covering the tropical and subtropical regions of the western Atlantic Ocean. The occurrence of great river effluents in the Gulf of Mexico, and along the coast of South America, combined with the occurrence of very extensive coastal lagoon systems renders it a very productive region for penaeid prawns, and these resources are perhaps more fully exploited here than anywhere also in the world mainly because of their proximity to the great crustacean markets of North America.

A. Lobster resources

Two species of spiny lobster occur in this region, both of them ranging rather widely from Bermuda, through the Gulf of Mexico and the Caribbean area, to the Atlantic coast of South America; these are *Panulirus argus* and *P. laevicauda*. The common lobster *Homarus americanus* has in recent years been trawled in deep water off Virginia and North Carolina, production reaching 75 tons annually.

The landings of these two species are partitioned between five countries as tabulated below:

Regional landings of spiny lobsters

Country	1961	1962	1963	1964	1965
Bahamas	-	-	-	-	1.2
Cuba	8.2	7.5	7.4	6.6	9.1
Mexico	-	-	0.2	0.2	0.1
U.S.A.	1.3	1.4	1.4	1.6	2.8
Venezuela	0.1	0.1	0.1	0.2	0.1
TOTAL	9.6	9.0	9.1	8.0	13.3 (tons x 10^3)

Production from this region is now approaching 14.0 x 10^3 tons annually and although some areas, as around Cuba and Florida, the stocks are probably rather heavily exploited, it is reasonable to suppose that further development of the fishery is possible in the other relatively under-developed Antillean islands, and it is, therefore, guessed that a 50% increase over present production is likely to be possible. The potential of this region is, therefore, for present purposes, set at 21.0 x 10^3 tons annually. It is to be expected that the greatest increase in production will come from the islands of

Jamaica, Dominica, and the Virgin Islands, with perhaps some new production from the eastern coast of Central America.

B. Crab resources

The greatest production of crabs in this region comes from the blue swimming crab and the Atlantic and Gulf coasts of the USA, *Callinectes sapidus*. The production from this fishery is considerably higher on the Atlantic than the Gulf coast of the U.S.A. but appears to have reached a point near its maximum sustainable production. The rather stable production in the last 5 years is probably due to a combination of resource limitation, and to the fact that the relatively low-priced products from this fishery still demand relatively high labor costs, and for this reason the northern fisheries of the Atlantic coast are declining relative to the remainder. The USA catches in recent years are as tabulated below:

US landings of blue crab (*Callinectes sapidus*)

1961 - 69.3 1964 - 71.3
1962 - 70.4 1965 - 75.9
1963 - 65.9 1966 - 71.9 (1966 - Atlantic-58.0
- Gulf-13.9) - (tons x 10^3)

A small number of other species of crabs are also exploited in the U.S.A. and the rest of the region, these in recent years obtaining a production rate of only about 2.0 x 10^3 tons a year. The statistical category 'various crustacea' reaches 5.0 to 6.0 x 10^3 tons annually in the region as a whole and probably contains a rather large percentage of crabs of various species, probably dominated by swimming crabs throughout the Caribbean and Central America. The potential of crabs from the region is extremely difficult to guess and for present purposes is set at the extremely conservative level of 80.0 x 10^3 tons annually, which is very little in excess of the present blue crab production off the U.S.A. It may very well be that this figure should rather have been set, and will prove in the long run to be 150.0 x 10^3 tons annually in view of recent (1968) indications on increased production on the Texas coast.

C. Prawn resources

It is these which are the most valuable and largest crustacean resources of the region and this is one of the major centres of prawn production of the world. Approximately 10 taxa of shrimps and prawns are currently exploited and of these 7 are shallow-living members of the genus *Penaeus*, the adults of which live upon the continental shelf, spawn there, and as far as is known pass their juvenile period in coastal lagoons. Two species of penaeids not of this genus and smaller in size having a shallow continental shelf ecology but without entering lagoons in the juvenile stage are also exploited, as is a single species of deep-living penaeid which occurs throughout the entire region on the upper parts of the continental slope. The exploited species with their scientific and industrial names and indication of their ranges within the region are given in the following tabulation:

Penaeus setiferus - white shrimp - New York to Campeche, Mexico
P. schmitti - camarón blanco - Honduras to Brasil
P. aztecus aztecus - brown shrimp - Massachusetts to Campeche
P. aztecus subtilis - camarón marrón - Honduras to Brazil
P. duorarum duorarum - pink shrimp - Chesapeake Bay to Mexico
P. d. notialis - caramel shrimp - Cuba to Brazil
P. brasiliensis - spotted pink shrimp - disjunct, Carolinas to Brasil
Xiphopeneus kroyeri - seabob - North Carolina to Brasil
Sicyonia brevirostris - rock shrimp - Virginia to Yucatan
Hymenopenaeus robustus - royal red shrimp - entire region

The white shrimp, *Penaeus setiferus*, has three centres of abundance where it is presently fished intensively. These are (1) off Georgia and northeastern Florida on the Atlantic coast of the USA, (2) off the coast of Louisiana on the Gulf coast of the USA, and (3) near Isla del Carmen, Campeche, on the eastern coast of Mexico.

The camarón blanco, *P. schmitti*, is more dispersed than the above species, and fishable concentrations occur especially off Cuba, off the Honduras-Nicaragua area, and off Venezuela, but in none of these places do stocks appear to be comparable in density to those of *P. setiferus* off Louisiana.

P. aztecus aztecus, the brown shrimp, occurs in four principal fishable concentrations: on the Atlantic coast of the USA off the Carolinas; in the Gulf of Mexico between the Mississippi and north-eastern Mexico; from the north of Tampico to Veracrus, Mexico; and finally along the coast of Tabasco and south-western Campeche, Mexico. The area of greatest abundance is in the north-central and north-western Gulf of Mexico. The principal stocks of *P. a. subtilis* appear to be to the south of this region along the coasts of Guyana, Surinam, French Guiana, and Brasil, and this species is only of importance in Region V along the coast of Venezuela.

P. duorarum duorarum occurs in two great concentrations, one along the southwest coast of Florida and the other on the Campeche banks off the east coast of Mexico. *P. d. notialis* occurs in fishable concentrations only at Cuba, the Honduras-Nicaragua area, and in the Gulf of Venezuela.

P. brasiliensis is not a great commercial importance in this region, except in the region from Cabo Catoche to Isla Mujeres, Mexico, the coast of Honduras and Nicaragua, and to some extent to Colombia and Venezuela. The largest stocks are apparently to the south of the region.

Commercial concentrations of the seabob, *Xiphopeneus kroyeri*, occur as follows: in the northern Gulf of Mexico, particularly to the west of the mouth of the Mississippi River; off Nicaragua; off eastern Venezuela; and off Trinidad. The largest stocks of this species are also to the south of this region. Known concentrations of the rock shrimp, *Sicyonia brevirostris*, occur from about Charleston, South Carolina to New Smyrna, Florida; in the north-western Gulf of Mexico; and in the Gulf of Campeche.

The deep-water shrimp, *Hymenopenaeus robustus*, known to the trade as the royal red shrimp, is the only species of deep-water crustacean considered in this area, although a number of other species occur with a rather similar ecology. There are three localities where fishable concentrations of the royal red shrimp are known to exist. These are along the coast of the USA and are located (1) off the east coast of Florida between latitude 27-31°N, (2) along the Florida Straits between longitudes 82-84°W, and (3) southeast of the Mississippi River Delta between longitudes 87-91°W. These grounds are named, respectively, St. Augustine, Dry Tortugas, and Mississippi Delta.

In addition to these species which are discussed above, and on which the present production in the region is based, there are of course also many other species of prawns and shrimps in the area, these being mostly of small size (such as those of the genera *Parapenaeus*, *Penaeopsis*, and *Trachypeneus*) that may or may not be taken and utilised incidentally with present commercial operations, and which may or may not have future potential as a commercial resource. These have not been included either because they are not reported in present landings or because it is unlikely that specific fisheries will develop in the foreseeable future from them. Also not included in the present consideration are the deep-water penaeids (*Aristaeomorpha foliacea*, *Aristeus antennatus*, *Penaeopsis serrata*, and *Plesiopenaeus edwardsianus*), and the pandalid *Plesionika edwardsii* have been reported on numerous occasions as occurring throughout the area, but none of these except *Penaeopsis serrata* (which is of small size) has been located in concentrations sufficient to suggest supporting the commercial fishery. The following tabulation summarises the present production of all species of prawn throughout the area by countries, and their estimated potential production. This cannot be broken down by species, as in almost every case the available national statistics are not stratified by species.

Country	Present	Potential
U.S.A.	78.7	102.0-127.0
Cuba	2.0	2.5
Mexico	30.9	33.0
Bahamas, Antilles	1.0	2.0
British Honduras	0.2	0.4
Guatemala	+	0.2
Honduras	2.1	3.0
Nicaragua	2.1	4.0
Costa Rica	+	0.2
Panama	+	0.2
Colombia	0.4	2.0
Venezuela	7.8	11.0
TOTAL	125.0	160.0-185.0 (tons x 10^3)

The estimates of present production or current production in the above table have been derived by Lindner, not from single recent years data bur rather from long-term averages. For instance, the US current production is derived from the 10-year average, 1958-67; the Mexican current production is based on the 9-year average, 1958-66 and includes landings of US vessels whose catches were made off the coast of Mexico. In some cases, such as that of Nicaragua, the estimates is rather made on the best available data even though this is for only a single year, in this case 1966, and from landings in that year by US vessels whose catches were reported as having been made off the coast of Nicaragua. The data from Venezuela and Mexico are probably not very reliable as a siseable quantity of the landings in these areas are reported as "heads-on" in the data but in fact have probably been headed before landing; for these two countries, therefore, a factor of 1.68 to convert headless landings to live weight has been used. It was necessary to group all countries and entities throughout the Bahamas, the Greater and Lesser Antilles, with the exception of Cuba, for although practically all have small localised shrimp fisheries their magnitude is not large nor is it likely to become so, and available landing data are so scanty that both estimated production and potential production are really only guesses.

It should be noted that the estimates of potential landings given in the above tabulation include 15.0-40.0 tons from the US fishery which might be expected eventually to accrue by changing present management procedures. Eliminating this accrual from good management we arrive at little more than 140.0 x 10^3 tons as the potential we can expect by increased fishing in some localities and by fishing species which are not now utilised. In other words we can expect only about a 16% gain in landings by increasing our fishing effort. It would be quite unrealistic at the present moment to attempt to estimate what improved management procedures might accomplish in the remainder of the region and although these might significantly lift the final estimated potential production this is not done at the present as it would be entirely unrealistic.

D. Total resource potential of Region V

The estimates of present production and of potential production discussed above are tabulated below:

	Present	Potential
Lobsters		
Panulirus spp.	13.3	21.0
Crabs		
Callinectes spp.	74.9	80.0
Others	2.0	
Prawns		
Penaeid and Crangonid prawns and shrimps	125.0	160.0
TOTAL	215.2	261.0 (tons x 10^3)

The rather modest potential increase in production suggested for this region is undoubtedly a function of the relatively high level of exploitation already achieved, and which is discussed in the text above.

Region VI - Eastern Central Atlantic

Present catches are low, less than 5.0 x 10^3 tons; resources comprise crayfish of several species, less than 10 species of penaeid prawns, and a few other minor species. Deliberate exploration for crustaceans has been carried out only in the Bight of Biafra, and the unsatisfactory data for crustacean from fish resource surveys make numerical projections of potential resources, and future yields very subjective.

A. Lobster resource

(i) *Palinurus mauritanicus*

Habitat: west coast of Africa from 18-25°N, 60-600 m, especially at 200 m on the Arguin Bank. Actual landings: 1963 - 2.5 x 10^3 tons from 40 French and Spanish vessels. Potential: presently over-fished (Postel 1967).

(ii) Palinurus charlestoni

Habitat: Cape Verde Islands, 150-300 m. Actual landings: 10-20 tons. Potential: perhaps 1,000 tons with other species (Postel 1967).

(iii) Panulirus regius

Habitat: from Cape Juby in Morocco to the south of Angola, including Cape Verde and Gulf of Guinea Islands; down to 40 m, but mostly at <20m, on rocky and other hard bottoms. Actual landings: 200-500 tons from Senegal-Mauritania directly to France; 75-125 tons at Dakar, Senegal; 10-50 tons in Ivory Coast; 10-20 tons in several other West African ports. Potential: negligible, perhaps 100 tons, in tropical Gulf of Guinea; 400 tons in Senegal and Mauritania; Angolan potential not known but possibly between 250-500 tons (Postel 1967, Williams 1968)

B. Prawn resources

(i) Penaeus duorarum

Habitat: in Eastern Atlantic the form commonly known under this name occurs from Cape Blanco to Angola; its identity with the Western Atlantic form does not appear to have been critically examined; coastal, down to 100 m, most common and abundant from 30-50 m in thermocline water and on soft mud associated with this depth. Juveniles in estuarine systems and lagoons. Actual landings: as tabulated below, in 1966, just under 3.5×10^3 tons for this region. Potential: only suggestion that MSY has presently been reached comes from Senegal rivers (e.g. R. Casamance). Elsewhere, exploitation is just starting, particularly from Nigerian ports, where production has now reached about 2.8×10^3 tons annually. Surveys, and patterns of exploitation, indicate that centres of production will be from Senegal to Guinea and from Dahomey to Gabon, including Fernando Po, with the greatest resources off the Niger Delta and in the Bight of Biafra. Catches off the US coast of the Gulf of Mexico of this and related species reaches 75.0×10^3 tons per year and it seems not improbable that a figure similar to this, between 50.0×10^3 tons and 100.0×10^3 tons is likely for the Gulf of Guinea, and could even be surpassed; the lower figure is adopted for present purposes.

Penaeus duorarum, landings in 1966

Senegal	- rivers	0.45
	- sea	0.52
Ivory Coast	- lagoons	0.30
	- sea	0.15
Dahomey	- lagoons	0.27
Nigeria	- sea	1.20
Cameroon	- sea	0.12
Gabon	- sea	+
Congo	- sea	+
Angola	- sea	0.15
TOTAL		3.16 (tons x 10^3)

(ii) Parapenaeopsis atlantica

Habitat: from Senegal to Angola, coastal and down to 60 m, but most abundant at 10-40 m; juveniles do not enter estuaries and lagoons. Actual landings: statistically, not generally separated from those of P. duorarum, and only in Ivory Coast and Congo are data available: in the former from 15-30 tons, in the latter from 1-5 tons annually appear to be landed. Potential: limited, but specialized fisheries may develop, as for the 'seabob' and other shrimps smaller than P. duorarum in the Gulf of Mexico. Impossible to quantify an estimate at this moment.

(iii) Parapenaeus longirostris

Habitat: Mediterranean and west coast of Africa south to Angola; in tropical region occurs on deeper parts of the shelf especially between 150-300 m. Actual landings: negligible, less than 50 tons annually by a few Spanish vessels north of Cape Verde. Potential: although survey data indicate the presence of this species throughout the Gulf of Guinea, it is not presently possible to quantify the potential yield (Crosnier 1967, Monod 1967, Williams 1968).

(iv) *Plesiopenaeus edwardsianus*; *Plesionika martia*; *Aristeus varideus*; *A. antennatus*; *Glyphus marsupialis*

Habitat: these are the main elements of a shrimp fauna on the upper part of the continental slope which occurs probably throughout the inter-tropical region from 200-900 m, each species probably having a preferred depth range. Actual landings: unknown, but some exploitation by Spanish trawlers off Sierra Leone and Senegal, landing in Las Palmas and Huelva. Potential: unquantifiable, but by analogy with Mediterranean fishery for some of these, and other related species with similar ecology, a yield of 10.0 x 10^3 tons annually in the tropical zone could be postulated (Crosnier 1967, Massuti MS., Monod 1967, Ivanov 1964, Williams 1968).

(v) *Palaemon hastatus*; *Hippolysmata hastatoides*

Habitat: estuaries and lagoons of tropical region, coming onto shelf areas during rainy season. Very shallow, along beaches. Actual landings: not known, but probably running into some hundreds of tons since beach seine catches at Lagos may take more than half-a-ton per haul during the season. Potential: unquantifiable, but probably less than 1,000 tons for the whole Gulf.

C. Crab resources

(i) *Portunus validus*; *Callinectes* spp.

Habitat: blue swimming crabs are common and abundant throughout the Gulf of Guinea, coastal and estuarine out to 50 m, usually shallower. *Portunus* dominant on continental shelf, *Callinectes* spp. in estuaries and lagoons. Actual landings: presently not quantified, and negligible except as minor element in indigenous fisheries. Trawler catches mostly discarded. Potential: by analogy with swimming crab fishery on eastern coast of USA, a yield of 10.0 x 10^3 tons for Gulf of Guinea appears possible, providing an economic basis was established. It seems extremely improbable that this potential will be realised in the foreseeable future, however.

D. Total potential resources of Region VI

The following tabulation is based on the production and potential estimates made above:

	Present	Potential
Lobsters		
Palinurus mauritanicus	2.5	2.0
P. charlestoni	+	1.0
P. regius	+	1.0
	(2.5)	(4.0)
Crabs		
Portunus validus	+	10.0
		(10.0)
Prawns		
Penaeus duorarum	4.6	50.0
Parapenaeopsis atlantica	+	1.0
Parapenaeus longirostris	+	1.0
Deep penaeids	+	10.0
Palaemon hastatus *Hippolysmata hastatoides* }	+	1.0
	(4.6)	(63.0)
TOTAL	>6.0	77.0 (tons x 10^3)

That the suggested increase in production for this region is relatively large is a reflection of the fact that it is only in the last few years that exploitation of the most important crustacean resources, those of *Penaeus duorarum*, has been started. In the present state of knowledge of the stocks of this species the suggestion made here as to potential production must be extremely subjectiv

Region VII - Western Indian Ocean

This region extends northwards from the boundary between South Africa and Mozambique along the coast of east Africa and around the Arabian Sea up to the western coast of Ceylon. It is one of the larger and more diverse regions and contains a very high number of species of crustacea, some of which support important fisheries.

A. Rock lobster resources

There appear to be no major resources, or centres of production, of rock lobsters in this region which is to the north of the important stocks of Jasus lalandii in southern Africa. Only around the Kerguelen Island in the extreme southern part of this region is there a rock lobster resource of any abundance, and this is neither very extensive, nor are there good production figures for it, but it is known to be exploited by French langouste boats, and the species which is exploited there and in small amounts round New Amsterdam and St. Paul Islands is believed to be Jasus paulensis.

Turning to the African coast, the Natal rock lobster Palinurus gilchristi extends northwards along the southern coast of Mozambique, where small quantities are taken off South Africa. The exploitation of this species is just beginning and a plant capable of freezing 2.5 x 10^3 tons annually has been installed in Lourenço Marques. This figure is here used as the potential for P. gilchristi from Natal and Mozambique. In the Mozambique Channel, Panulirus ornatus, P. longipes and P. versicolor are taken by a number of methods and produce approximately 150 tons annually. From the nature of the environment, and the distribution of these species, it is impossible to employ industrial methods of fishing, and the production of these species in this area will be determined by the amount of individual effort which local fishermen are prepared to put into the fishery. Postel suggests a total production of 600-700 tons from this area annually.

On the southeast coast of Madagascar, P. homarus and P. penicillatus are taken with nets; the rate of production is extremely low, of the order of 20 tons annually. In the Mascarene Islands, P. penicillatus, P. ornatus and P. longipes are taken in small quantities along the coral reefs by local divers. In the Red Sea and the Gulf of Aden, P. penicillatus and P. ornatus are again present, and are taken in very small quantities by local divers.

Recently promising catches of deep-sea labster, Puerulus sewelli have been taken in deep water (100-150 fm, ca 200-300 m) off Cochin.

In sum, it appears unlikely that the production of spiny lobsters throughout the region will significantly exceed 3.0 x 10^3 tons annually.

B. Crab resources

It is presently impossible to estimate the catches of crabs from this region. The rather large quantities of 'other crustacea' reported in the landing statistics of India and Pakistan suggest that significant quantities of crabs, probably mostly portunid swimming crabs, are produced but the present breakdown in statistics makes it impossible to define this.

The only studies of edible crabs in the Indian Ocean, from a commercial point of view, appears to be that of Guinot (1967a). The degree to which crabs are utilized in the Indian Ocean appears to vary very widely, especially for smaller species, and the potential yield from more widespread fishing than is practiced at the moment could be quite high, although Guinot attempts no estimates of production rates. He implies that at least some species, for example Portunus pelagicus, are rather heavily fished.

Off Mozambique, several species of crabs are landed in small quantities, partly as a by-product of the shrimp fishery. They include Schylla serrata, Portunus pelagica, and P. sanguinolenta. Possibly appreciable stocks of S. serrata (mangrove crab) occur in mangrove swamps along the entire East African coast.

C. Shrimp and prawn resources

In Mozambique, just to the north of the South African border, the important species appear to be Penaeus indicus, P. monodon, P. semisulcatus, and Metapenaeus monoceros. P. indicus constitutes about 70% of the catches. Species of secondary importance are P. japonicus and P. latisulcatus. The annual production in 1,000 metric tons of these species on the coast of Mozambique is given in the following tabulation; this production comes from an area of about 3,000 km^2 of offshore trawling grounds and 1,000 km^2 of inshore bays and estuaries, of which the inshore areas of Delagoa Bay, Inhambane, the mouth of the Save River and Mecufi are the most important.

	1964	1965	1966
Offshore trawling	-	0.1	0.1
Inshore fisheries (beach seines and traps)	0.4	0.4	0.6
TOTAL	0.4	0.5	0.7

It is thought that commercially exploitable stocks of Hymenopenaeus triarthrus are present in deeper water off Mosambique, below about 200 fm, together with species of Aristeus and Hemipenaeus which might contribute to this potential fishery. It seems likely that future production may expand in the shallow areas to the north and south of the Limpopo River, along the Sofala Bank and as far north as the Zambesi River mouth; in deeper water, at a depth of around 250 fm, prawns are abundant from Moma to Mosambique Island.

No detailed data are available for the fisheries off Madagascar which are based largely on stake traps and are much diffused, but statistics are maintained by one firm which took 30 tons from 20 traps during 1959; FAO statistics indicate 1.3 x 10^3 tons in 1966 and this number seems reasonable. Penaeus indicus probably constitutes about 70% of the catches, P. monodon 15% and Metapenaeus monoceros a further 15%; Penaeus japonicus and Trachypenaeus curvirostris may be common at times but are never caught in large quantities by present methods. Some shrimp trawlers may have recently begun operations but no details are available of their landings. A small fishery for Nephrops andamanicus has recently developed.

There are no good statistical data for present prawn and shrimp production from Tanzania though the FAO statistics mention a production rate of 0.5 x 10^3 tons annually. It is known that small Japanese-operated trawlers have been exploring the coast, and recently have been reported to be taking 10 tons per day from the region north of Dar-es-Salaam. It is likely from survey work in this area that the species which they are taking are primarily Penaeus monodon, P. semisulcatus and P. indicus. There are small subsistence level fisheries using fixed traps in the Rufiji Delta where small quantitie of large P. monodon and all sizes of P. indicus together with small quantities of Metapenaeus spp. constitute the catches. On the coast of Kenya, small boat operations in the extreme south (Shimoni), and in the extreme north (Lamu) have been building up over the last 18 months but there is no record of their catch rate, nor of the species involved; it is considered likely, however, that the catch composition will not differ very much from that of Tanzania. There is no knowledge of prawn resources off the coast of Somalia, and there appears to be no fishery in that area. An annual spawning run of penaeid shrimps in the mouth of the Juba River has been recorded, and small numbers of penaeids are known to occur in the estuaries of other small rivers but these stocks have neither been quantified nor exploited.

In the Red Sea, the Gulf of Aden and off the southern Arabian Peninsula there are fisheries for Penaeus semisulcatus, P. japonicus, P. latisulcatus, Metapenaeus monoceros, M. stebbingi, and Trachypenaeus curvirostris, but only P. semisulcatus is likely to be important commercially. The only statistical data from this area are those from Egypt which in 1963 quoted a total shrimp and prawn catch of 10.4 x 10^3 tons but without any record of how much, if any, of this catch was taken from the Red Sea, or the Gulf of Aden. A very small seasonal cast-net fishery for prawns exists in Aden at the inlets to the salt pans.

In the Persian and Arabian Gulfs an important prawn fishery has grown up in recent years, in which Penaeus semisulcatus dominates the catches and which also include small quantities of P. latisulcatus and Metapenaeus affinis, except for the Hormus Strait-Bandar Abbas region where Penaeus merguiensis may be the dominant species in the catches. The estimated total commercial catches from this area in recent years are tabulated below.

1959 - 0.6
1960 - 1.1
1961 - 1.7
1962 - 0.9
1963 - 3.1
1964 - 5.8
1965 - 11.4
1966 - 16.1
1967 - 14.6 (tons x 10^3)

The total area of the Persian Gulf is about 239.0 x 10^3 km^2; of this total about 142.8 x 10^3 km^2 is shallower than 20 fm (ca 36 m). The exploitable area of the Gulf is so limited by sand banks and coral reefs along the Arabian side, and by soft mud in waters deeper than about 25 fm (ca 45 m), that only 10-20% of the total area may be trawlable, say 35.0 x 10^3 km^2.

In the past 2 years, 1966 and 1967, the catch per unit of effort has declined and in 1967 the total production also fell though it increased again in 1968. Some concern has been expressed for the stocks, but a very recent assessment has concluded that there is no clear evidence as yet that the decrease in total catch was due to fishing pressure either directly or indirectly. It has been acknowledged, however, that in the more heavily-fished areas a further increase in fishing effort might reduce the total catch. In view of the present status of the stocks, it would be unrealistic to expect any further considerable expansion of the fishery, although some further developments in the more lightly fished areas is possible, and a maximum sustained production rate of 15.0 x 10^3 tons is used here for these Gulfs.

Off West Pakistan, Penaeus merguiensis is recorded as outnumbering all other prawn species in catches from coastal waters, with Penaeus semisulcatus, P. penicillatus, Metapenaeus monoceros, and Parapenaeopsis stylifera also being important. Caridean species do not appear to be important. The total production of shrimps and prawns from these resources in the last few years is as follows:

1961 - 6.6	1965 - 18.0
1962 - 4.6	1966 - 18.2
1963 - 9.2	1967 - 17.2
1964 - 16.1	1968 - 15.5 (tons x 10^3)

Commercial fishing by shrimp trawlers is conducted in the 7-23 m depth zone along the 300 ml of this coast of Pakistan, and by beach seines in the creeks. The total fishing area is about 11.0x$10^3$$km^2$. The catch statistics show a stabilisation of catch since 1964 despite an increase in the number of boats from 226 in 1964 to 363 in 1968. Most of the fishing is concentrated within about 50 mi of Karachi. These grounds are probably fully exploited, but exploratory fishing has shown that good catches can be obtained on most distant grounds, especially south of the Indies. These grounds do not seem to be heavily exploited, and the shrimp there are noticeably bigger. A sustained yield of 25.0 x 10^3 tons should be possible with a more rational distribution of fishing.

The present fisheries along the west coast of India are rather heterogeneous in their specific composition, and productivity varies markedly along the coast. On the northwest coast (Maharashtra and Gujerat) which produces over 50% of the catch, the prawns are rather small species, being dominated by Metapenaeus affinis, Parapenaeopsis hardwickii, P. stylifera and Solenocera indica. The dominant caridean species are Palaemon tenuipes and Hippolysmata ensirostris, and these are caught in enormous numbers, together with the sergestid Acetes indicus, from April-May and from November-December. The fishing techniques for all these species are fixed bag and stake nets.

Along the south-western coast of India there is a bigger variety of fishing gear used and the catch is distributed in the approximate proportions 3:3:2:sea (trawls, boat-seines):backwaters (stake nets, dipnets, cast nets):paddy fields. The most important species are Penaeus indicus, Metapenaeus dobsoni, M. affinis and M. monoceros (marine and backwaters), Parapenaeopsis stylifera (only at sea), and Macrobrachium rosenbergii (only riverine). The purely fresh-water species are of small importance and M. rosenbergii is caught in very limited quantities in certain areas only. The production from the Indian west coast of penaeids and caridean prawns in recent years is tabulated below:

Year	Penaeid	Caridean	Total
1960*	27.5	35.0	62.5
1961*	32.9	22.0	54.9
1962*	42.2	34.6	76.8
1963*	30.7	39.5	70.3
1964*	52.0	30.2	82.2
1965**	28.0	41.0	69.0
1966**	45.7	34.7	80.4 (tons x 10^3)

Notes - * Data from Indian Fisheries Department

** Data from FAO

The littoral prawns which are currently exploited occur down to about 30 m along the west coast of India but all the best areas are inside the 35 m line. Survey fishing in the 100-200 fm (180-360 m) range shows fairly large numbers of *Penaeopsis rectacuta* and *Aristeus semidentatus*, but there is no estimate of the likely production from these deep water resources. From the manner in which the production has been rising in the last 5 years and from the fact that no production has yet been made from deep water resources it is considered for present purposes that a 20% increase over present production is quite likely, and a total production of 100.0 x 10^3 tons for the total west coast of India catch in the future years is, therefore, assumed.

Thirty-one species of penaeid prawn have been recorded from the waters of Ceylon. No analysis of the specific composition of prawn catches has been undertaken but the following species have been classified as being abundant on the west coast: *Penaeus indicus*, *P. merguiensis*, *P. semisulcatus*, *Metapenaeus dobsoni* (most abundant of all penaeids, but small in size), *Trachypenaeus salaco*, and *Parapenaeopsis coromandelica*. Only the first three of these species are likely to be of major commercial importance, and caridean prawns are of negligible importance. The catch in 1965 was 770 metric tons from Ceylon and it does not appear that the catches have yet passed the level of 1.0 x 10^3 tons annually which is suggested here as the potential production from the west coast of Ceylon.

The prawn catches in the Western Indian Ocean may be summarised as follows: *Penaeus indicus*, one of the species in which the juvenile passes a part of its life in a fresh or brackish water environment is the dominant prawn along most of the southern part of the East African coastline, and of Madagascar. Further northward (with increasingly arid terrestrial conditions) the dominant species are those which are less dependent on fresh-water habitats, such as *P. semisulcatus* and *P. merguiensis*, although post-larvae of both these species will migrate into fresh or brackish water areas if they can. These three species may all grow to a good size. The west coast of India has a much more varied penaeid fauna than do the regions to the west, and some elements are rather small in individual size; it is difficult to be certain which are the most important species in the absence of objective data, but further to the south, off Ceylon, all three of those mentioned above are important in the catches.

Whereever it is taken, namely throughout the region excepting the Red Sea, *Penaeus monodon* usually makes an important element of the catches, not because it is abundant but because of its very large adult size and excellent price in the market.

D. Total resource potential of Region VII

From calculations based upon the catch per km^2 per year over various prawning grounds in the Western Indian Ocean and on the assumed total area of hypothetical prawning grounds, Hall suggests that the total potential production of penaeids in the Western Indian Ocean might be approximately twice the present level and the production of caridean shrimps would be additional to this. This would give a total production of at least 200.0 x 10^3 tons annually and this is used as the regional potential for present purposes even though it is not supported in detail in the following tabulation of present and potential production in Region VII.

	Present*	Potential**
Spiny lobsters		
Africa	<0.3	3.0
Madagascar	<0.1 (0.4)	<0.1 (3.1)
Penaeid prawns		
Mozambique	0.7	1.0
Tanzania	0.1	0.5
Kenya	0.1	0.5
Red Sea, etc.	5.0	5.0
Persian Gulf, etc.	16.1	20.0
West Pakistan	18.2	25.0
India, west coast	45.7	50.0
Ceylon, west coast	0.8	1.0
Madagascar	1.3 (86.6)	1.3 (104.0)
Caridean shrimps		
India, west coast	34.7 (34.7)	40.0(?) (40.0)
TOTAL	121.7	147.4 (tons x 10^3) (-200.0, Hall)

Notes - * Data from most recent available year.

** Because of lack of data on present production a potential has not been guessed for portunid crabs, but this may be large.

Region VIII - Eastern Indian Ocean

This region extends from the east coast of Ceylon, around the Bay of Bengal and includes, at its extreme southeast corner, the western coast of Australia, the Indian Ocean coasts of Sumatra and Java, and the west coast of Malaya and Thailand.

A. Spiny lobster resources

The only part of this region for which there are data on the occurrence of spiny lobsters and on the production of fisheries for them is Western Australia. Several species occur here but only one, *Panulirus longipes cygnus* supports the important fishery. This species occurs from 21°-34°S along the west coast of Australia, the majority of the commercial catch being taken from 28°-32°S, the crayfish boats operating from a number of ports between Fremantle and Geraldton. Fishing grounds are approximately 24.0 x 10^3 km^2 of water shallower than 155 m, though not all of this area has a substrate suitable for this species. During the "red crayfish season", the boats may operate from offshore islands such as the Houtman Abrolhos Islands. The fishing season extends from late spring through to the next southern winter and catch data are, therefore, given for pairs of years. The production for recent seasons follows:

1958-59 - 8.0
1959-60 - 8.8
1960-61 - 8.2
1961-62 - 8.7
1962-63 - 9.1
1963-64 - 8.1
1964-65 - 7.4
1965-66 - 8.0
1966-67 - 8.6
1967-68 - 9.9 x 10^3 tons

A sustainable level of catch of 8 ± 1 x 10^3 tons per year has been suggested (Bowen and Chittleborough 1966, Sheard 1962). Present exploitation rates are high (exceeding 60%).

The southern crayfish (*Jasus novaehollandiae*) is common on the coast to the south of 33°S, but surveys have failed to find sufficient to support a fishery in this region.

On the western coast of Australia north of 22°S, several species of panulirids occur (*P. versicolor*, *P. penicillatus*, *P. ornatus* and *P. polyphagus*). Local areas of abundance have been claimed for certain of these, but test fishing failed to obtain any catch although various types of traps and bait were used. The potential resource of these species is not known, but it is not considered to be high in this region.

B. Crab resources

Crabs are taken in small quantities in Western Australia and throughout the region. The same remarks as were made for Region VII apply also to this region in regard to this resource, which is presently unquantifiable.

C. Shrimp and prawn resources

The catch of prawns along the east coast of Ceylon in 1965 amounted to 1.5 x 10^3 tons; no analysis of the specific composition of the catches has been made, but the following species have been recorded as being abundant: *Penaeus indicus*, *P. merguiensis*, *P. semisulcatus*, *Metapenaeus affinis*, *M. ensis*, *M. dobsoni* (most abundant of all penaeids, but rather small in size), *M. elegans*, *Metapenaeopsis stridulans*, *M. toloensis*, *Trachypeneus salaco*, *Atypopeneus stenodactylus*. The first three of these species are undoubtedly of the greatest importance but the others, excluding *T. salaco*, may be abundant locally. Caridean species are of negligible importance in this area.

There are not data available on the status of the exploited stocks, but the 1965 catch apparently came entirely from the 0-20 fm range, so the deeper resources at the edge of the continental shelf which may be assumed to exist have neither been surveyed, nor are in production.

The prawn fisheries along the east coast of India amount to 10.0 to 12.0 x 10^3 tons annually; the most important species are *Penaeus indicus*, *P. monodon*, *P. semisulcatus*, *Metapenaeus dobsoni*, *M. affinis*, *M. brevicornis* and the caridean species *Palaemon styliferus*. There are four areas within which the resources are most abundant: (a) rivers and other entirely freshwater areas, dominated by species of *Palaemon* and *Macrobranchium*, of which *M. rosenbergii* is the largest, although *P. styliferus* dominates the riverine catches numerically; (b) the Chilka, Kolleru and Pulicat Lakes, which are major coastal lagoons, an which produce more than 1.0 x 10^3 tons annually from small locally-made shrimp traps. *P. indicus* constitutes some 65% of these catches, with *P. monodon* and *Metapenaeus monoceros* contributing about 15% each; (c) the deltaic areas of the River Ganges which also produce about 1.0 x 10^3 tons annually and where *Metapenaeus brevicornis*, *Parapenaeopsis sculptilis*, *Palaemon styliferus* and *Acetes indicus* are the most important species; (d) offshore areas accounting for most of the balance of the prawn catches, and producing almost 10.0 x 10^3 tons annually. The catches of the Andaman and Laccadive Islands are not included in these statistics, nor in those tabulated below, and are less than 5 metric tons annually. The total catches from the above four areas during recent years are tabulated below.

Year	Penaeid	Caridean	Total
1960*	4.3	1.3	5.5
1961*	6.2	1.7	7.9
1962*	6.0	0.4	6.4
1963*	10.3	1.0	11.3
1964*	11.4	1.3	12.7
1965**	7.9	0.4	8.3
1966**	9.8	0.7	10.5 (tons x 10^3)

Notes - * Data from Indian Fisheries Department
** Data from FAO

Again, as for the coast of Ceylon, the entire production from the Indian sector of the Bay of Bengal is from shallow water from 0-20 fm and does not include any production from such deeper resources at the edge of the continental shelf and below as may be assumed to exist.

Along the coast of East Pakistan, a fishery for palaemonid species flourishes during the rainy season when the salinity of the coastal waters is lowered by the rains, but during the remainder of the year the catches are dominated by penaeids, among which the most abundant appear to be *Penaeus semisulcatus*, referred to as the most important in the deltaic region and *P. indicus* and *Parapenaeopsis sculptilis*.

Commercial fishing is currently carried out entirely in estuarine areas, and has hardly expanded yet onto the continental shelf and certainly no catches are produced from the deeper resources which presumably exist in the Bay of Bengal.

There are no published data on the prawn and shrimp fishery of Burma, since the statements that the 1953 to 1954 season's catch from the floating prawn traps in the deltaic area took approximately 5.0 x 10^3 metric tons. There are certainly very extensive unexploited resources in the shallow continental shelf area but these are apparently unknown at present, although Hall suggests that the Gulf of Martaban (which exceeds 35.0 x 10^3 km^2 in area) may be particularly valuable.

There are no good data on the prawn fisheries from the west coast of Thailand, for it is not possible to separate the catches from the east and west coasts in the fishery statistics from this country, which show that the total catch of marine and estuarine prawns in 1966 was 45.3 x 10^3 tons. It is considered however that the bulk of these catches came from the east side of the peninsula (see Region IX), and based on the relative length of the coastlines, the distribution of the human populations, and the location of major rivers, Hall suggests that possibly 10% of the catch may be associated with the Indian Ocean, e.g. marine and estuarine - 4.5 x 10^3 tons; freshwater - 0.3 x 10^3 tons.

By comparison with the specific composition of catches from Penang and the Alor Star area of northern Malaysia it is probably that the dominant marine species on the west coast of Thailand are *Parapenaeopsis harwickii*, *P. hungerfordi*, *P. sculptilis*, *P. coromandelica*, *Penaeus merguiensis*, *Metapenaeus brevicornis* and *M. affinis*. In the mangrove areas with a fresh or brackish environment the dominant species are likely to be *Penaeus indicus*, and *Metapenaeus ensis*.

There is no recent information on the Indonesian prawn fishery which will enable us to separate the catch along the Indian Ocean coast of Sumatra and Java from that along their northern coast; but, bearing in mind the steepness of the Indian Ocean coastline profile of these islands compared with the Strait of Malacca/Java Sea profile, and the concentration of populations on the side away from the Indian Ocean, possibly 5% of the catch should be attributed to the Indian Ocean. Hall suggests that this is a total of a little less than 1.0 x 103 tons annually. The catches from Indonesia, like those from India, consist of four fairly distinct elements: (a) the marine catch taken by trawling, (b) the penaeid catch taken from prawn ponds, of which the most important species are *Penaeus indicus*, *P. semisulcatus* which is appreciated for its large size, *Metapenaeus ensis* and *M. brevicornis*, (c) the non-penaeid shrimp catch consisting mostly of fairly large freshwater species of which *Macrobrachium rosenbergii* is the most appreciated and very widely distributed. Other species quoted are *M. equidens*, *M. pilimanus*, *M. sintangense* and *M. lar*, (d) the non-penaeid catch consisting mainly of small atyids and Caridina species, but including also mysids and possibly *Acetes* spp, the importance of which lies in their vast numbers of small individuals.

Along the west coast of Malaysia the fishery for Udang prawns, or large penaeids, is not detailed statistically but in the south the important species are probably the same as those at Singapore, with the following being the most abundant: *Metapenaeus ensis*; *Penaeus indicus*; *Metapenaeus burkenroadi* and *affinis*. Local variations occur, so that inshore Malacca catches have *M. affinis* as a major element while *Penaeus merguiensis* is important in the northwest of Malaysia, where inshore fisheries tend to be dominated by *Parapenaeopsis* species, especially *P. hardwickii* and sometimes *P. coromandelica*. *Metapenaeopsis barbata* occurs in offshore catches occurring along with other species of this genus and other genera.

The present annual catch from the Udang prawn fisheries is of the order of 25.0 x 10^3 tons altogether, this figure being dominated by the west coast and Malacca Strait total of 21.0 x 10^3 tons. There are no exact data on the status of these prawn stocks, but there may be some over-fishing in the in the inshore areas, while there are also considerable areas of mangrove and offshore grounds which are scarcely exploited. Thus, the fishery can withstand considerable increase in intensity, and a total of, say, 35.0 x 10^3 tons does not appear impossible for this fishery in the foreseeable future.

The fishery for Udang baring shrimps depends on several species of Acetes. In the south *Acetes vulgaris* comprises most of the catches, but in the north *A. sibogae* is important, while *A. erythraeus*, *A. spiniger*, and *A. japonicus* occur generally. Perhaps all species of this genus except the planktonic *A. serrulatus* are of some importance locally or seasonally. The catch may sometimes contain small quantities of mysids such as *Mesopodopsis* but these are seldom important. Production figures are approximately 5.7 x 10^3 tons for the west coast and Malacca Straits and there are no indications that the fishery is over-exploited, as these small prawns occur everywhere in immense numbers. It seems certain that the production figures could be raised to about 7.5 x 10^3 tons annually. The freshwater shrimp *Macrobrachium rosengergii* is caught in estuaries, and is a valuable item of pond fish culture.

In addition to the above a fair quantity of small prawns is included in the landing statistics under the "mixed fish" and "manure fish" categories but there are no accurate data on the proportions. A fair percentage of beach catches certainly go unrecorded where they are used for local consumption by villagers, and there are also unrecorded subsistence fisheries in freshwater for *Atya spinipes*, species of *Macrobrachium* including *lanchesteri*, *geron*, *trompi*, *sintangense*, and *javanicum*. In our view all of these fisheries are currently negligible.

Collections made by the former Singapore Regional Fisheries Research Station now held in the University of Singapore Zoology Department indicate that there may be commercial quantities of the pandalid prawn *Plesionika martia* along the upper part of the continental slope off northern Sumatra and north-westernMalaysia, and this is entirely in agreement with assumptions that might have been made on the grounds of explorations in other parts of the tropical seas.

Finally, in the extreme south-easternpart of the region a trawl fishery is developing rapidly along the continental shelf of Western Australia, being presently concentrated mainly in Shark Bay and in Exmouth Gulf. Based on the exploitation of *Penaeus esculentus* (50% of production), *P. latisulcatus* (49%) and *P. merguiensis* (1%), this fishery has produced in recent years as follows:

1962 - 0.3
1963 - 0.7
1964 - 1.1
1965 - 1.1
1966 - 1.2
1967 - 2.2
1968 - 1.4
1969 - 2.1

Fishing operations reached Shark Bay in 1962 and Exmouth Gulf in 1964 and are presently extending to the northward; until this extension is completed, catches from this fishery will probably be regulated at somewhere near the present level by management procedures. A small fishery with handnets for *Metapenaeus bennettae* in the estuaries of Western Australia is not identifiable in currently available statistics and the landings are considered negligible for present purposes.

D. Present production and future potential of Region VIII

Apart from the coastline of north-westernAustralia the coasts of the Eastern Indian Ocean receive an abundant rainfall and the dominant species are those which spend a part of their juvenile lives in a fresh or brackish environment, and include: *Penaeus indicus*; *Metapenaeus monoceros*, *M. ensis*, *M. affinis* and *M. brevicornis*; *Penaeus semisulcatus* and *P. monodon* (which are appreciated for their size). Further offshore, species of *Parapeneopsis* may dominate in the catches and note must be taken especially of the small *Macrobrachium rosenbergii* which extends from India to North Australia and is the most appreciated of the non-penaeid species. No studies have been undertaken on the status of any of the stocks in the Eastern Indian Ocean but there can be no doubt that throughout much of the region there appears to be little or no offshore exploitation which suggests that the resources in general are under-exploited. The table indicates the present production of the various types of resource from each country in the region together with a tabulation of the estimates that have been made in the text on the potential resources. It is to be noted that the figure of 53.0 as the potential production from the Eastern Indian Ocean excluding Malaysia and Western Australia is derived from the estimates of Hall, who based his figures on an area, and catch rate per area basis.

	Present	Potential
Spiny lobsters		
Western Australia	8.6	8.0
Crabs		
Region	+	+
Prawns and shrimps		
Ceylon, east	1.5	53.0
India, east	10.5	
Pakistan, east	7.8	
Burma	5.0	
Thailand	4.8	
Indonesia	0.8	
Malaysia	26.7	42.6
Australia	2.1	5.0
TOTAL	67.5	108.6 (tons x 10^3)

Region IX - Western Central Pacific

This includes most of Oceania, the coast of Asia from Japan to Singapore and the islands and archipelagoes lying between Japan and New Guinea. Much of the region consists of enormous reaches of open ocean, sparsely studded with small islands, but paradoxically it also includes the greatest area of continental shelf occurring within tropical latitudes. The archipelagoes of the Philippines and Indonesia, together with the smaller island clusters and the coast of southeast Asia, include an immense length of tropical coast line there being 14.0 x 10^3 islands in the Philippines alone). This is a region of heavy rainfall and many rivers, creeks and lagoons open onto the continental shelf, and the coast itself is often low-lying and includes many sheltered, low salinity, muddy bays and gulfs. It is no surprise, therefore, to find that the statistics indicate a wealth of prawn resources, perhaps the greatest in the tropical seas, and largely unexploited.

A. Spiny lobsters and similar resources

The fishery for spiny lobsters is small by comparison with that of Australia and New Zealand, but some are taken in many places, notably Japan (1.6 x 10^3 tons per year), and Taiwan (0.1 x10^3 tons per year). It is probable that in many places the landings of spiny lobsters are hidden in statistics of other crustaceans, rather than being identified specifically.

Spiny lobsters occur throughout the tropical regions and are probably an extremely under-exploited resource in this region; although population densities are unlikely to be high in tropical latitudes the stocks are sufficient to support small fisheries. A few vessels from New Zealand have, at times, fished the Kermadecs and Tonga, among other islands.

It seems probable that an estimate of 5.0 x 10^3 tons is not too high an estimate for the potential annual yield from the whole of this vast region. Similar species, such as the *Nephrops andamanica* which occurs along the continental edge off Hong Kong, would contribute to this total. Flapjack lobsters, *Thenus orientalis*, are caught in the Gulf of Thailand and on a small scale off Malaysia and Singapore, but there are no exact figures on production.

B. Crab resources

Many species of crabs are taken throughout the region; though not specified in most of the statistics, these appear to be largely portunid swimming crabs of several general with *Scylla servata* and *Portunus pelagicus* predominating. This fishery is homologue of the blue crab fishery in the Western Atlantic.

Known catches of crabs in the region in 1965 were:

Malaysia	1.5
Thailand	11.0
Taiwan	1.8
Japan	25.0
TOTAL	39.3 (tons x 10^3)

It may be safely assumed that the real catches of the region are actually at least 50.0 x 10^3 tons per year, since in many places (such as the Philippines) crabs are certainly caught, but are not identified in the available statistics.

The relatively short coastline of the eastern seaboard of the USA produces about 75.0 x 10^3 tons of Callinectes per year at close to maximum exploitation levels; it is not unreasonable to suppose that Region IX, with its very much greater shelf area and length of coastline could produce twice this quantity or 150.0 x 10^3 tons per year. This may be a gross under-estimate and the appropriate factor may rather be x 10 than x 2.

C. Prawn resources

Here the data are rather better, and it will be convenient to discuss the resources by five sub-regions.

(i) The Sunda Islands and New Guinea

Indonesia

Data are rather sparse, but suggest that the resources are large and under-exploited. No detailed statistical data exist on present fisheries, which Ivanov (1964) places at 2.5 x 10^3 tons, and which primarily exploit Penaeus indicus and Metapenaeus ensis, though it is reasonably certain that all species which are of economic value in Malaysia are also fished by Indonesia. It is known also that Belachan shrimp (Acetes sp.) are exploited, as are Terasi (juvenile penaeids, etc., and Mysidacea) for use as shrimp paste. Freshwater Atya and Caridina are also fished on a subsistence scale in many areas, especially in the Celebes.

In general, this area is very rich in prawn resources, and Malayan fishermen consider it to be richer than their own waters; although the results of Indonesian resource surveys off Java and West Irian are yet to be published, it is reasonable to suppose that a potential of 100.0 10^3 tons is not too high for Indonesia. This is, however, purely conjectural.

Brunei

Contiguous to grounds exploited by Malaysian fishermen, there is known to be a small fishery here which primarily exploits Penaeus merguiensis. No production data are available, but it is probably less than 1.0 x 10^3 tons.

Sabah

Some 21 species of penaeids are known to occur in the local fishery, and Penaeus indicus and P. merguiensis are the most important; the present production is about 3.0 x 10^3 tons per year, heads-on, from an estimated exploited area of 7.0 to 10.0 x 10^3 km^2.

Control measures exist and only the western fishery region seems likely to be capable of expansion, to an uncertain extent. It is suggested that a fishery for Acetes spp. could be developed in mangrove areas, as in Brunei and Malaya.

A total potential of 4.0 x 10^3 tons may be resonably deducted from these observations.

Sarawak

Fishing is still on a small scale and though prawns (mostly Penaeus indicus, P. monodon, P. merguiensis and four species of Metapenaeus)are known to be present in commercial quantities, no production figures or estimates of potential are presently available. It is assumed here that a catch of at least 1.0 x 10^3 tons is possible annually.

Timor and Papua/New Guinea

No data are available for this area, though it is evident that resources must exist. From the size of the area, it seems that at least 10.0×10^3 tons could be taken.

Northern Territories, Australia

Exploitation of the northern, tropical prawn resources has only just begun, following resource surveys by CSIRO which indicate that the potential of this region exceeds that of the rest of Australia several-fold. A prawn-fishing base has been established on the Gulf of Carpentaria at Karumba, where 14 vessels landed 0.45×10^3 tons in 1967, and 40 vessels 1.36×10^3 tons up to August in 1968. Catches by mother-ship fleets of Japanese trawlers in the Gulf are not known, but are probably similar to the above.

The CSIRO resource surveys in the tropical northern regions indicate a potential of 11.4×10^3 tons for the Gulf of Carpentaria or 20.0×10^3 for the whole of the northern territory, and these estimates are certainly conservative.

(ii) Oceania

Tahiti

The only data available suggest a very small fishery for *Macrobrachium lar*, at subsistence level, and with a production probably $<1.0 \times 10^3$ tons.

Tonga

Some prawns are taken on a subsistence basis.

Samoa

Prawn resources are known to occur, but identity and magnitude entirely unknown.

Fiji

A resource survey indicates the presence of stocks of *Penaeus monodon* in commercial concentration, but no fishery has developed and potential is not known. A subsistence freshwater fishery for *Macrobrachium lar*, *M. australe* and *M. latimanus* occurs, but there are no production data although fishing said to be "quite heavy", and extension seems likely.

Guam and Marianas

There is a small subsistence fishery for *Macrobrachium lar*. Potential is very limited.

(iii) Asian coastline

Singapore

Prawn trawling offshore is incidental to fish trawling and only the larger prawns are saved from the catch; these include the following species: *Penaeus indicus*, *P. monodon*, *P. semisulcatus*, *Metapenaeus intermedius*, *Parapenaeopsis probata*, *P. hardwickii*, *Metapenaeopsis barbata*, and *M. merguiensis*. About 0.4×10^3 tons are obtained this way each year, and although there is no indication of the extent of potential fishing grounds, it is believed that offshore stocks would sustain a specialised fishery for prawns. It is rather likely that the potential for the offshore South China Sea coast of Malaya and Singapore would be at least 10.0×10^3 tons annually.

A varied catch is made of other, inshore, species of prawns with a variety of gear, mostly on a subsistence level, based on: *Metapenaeus affinis*, *M. lysianassa*, *Parapenaeopsis* spp., *Metapenaeopsis* spp., *Acetes* and *Palaemon*. Some of these catches are made incidentally in beach fishing. Production from such means approximates 0.4×10^3 tons at present.

Pond culture of penaeids produces 0.1×10^3 tons per year, 97% of the production comprises *Penaeus indicus*, *Metapenaeus burkenroadi*, *M. brevicornis*. Also important are *Penaeus monodon* and *P. semisulcatus* because of their high individual value.

Malaya (Johore and East Coast)

There is a fishery here which depends on the same species as at Singapore, and in which *Penaeus indicus*, *Metapenaeus ensis*, *M. burkenroadi* and *M. affinis* are dominant. Total production from this area is currently 3.4 x 10^3 tons, and there are indications that some of the inshore areas are already over-fished, though great areas of mangrove remain to be exploited; offshore areas are relatively virgin, but their potential is included in the offshore area discussed for Singapore. A potential, excluding offshore reaches of the South China Sea, of 5.0 x 10^3 tons seems probable for this area.

Thailand

Prawn catches by the Thai fishery in the Gulf and South China Sea adjacent have increased significantly in recent years:

1958 - 10.3 1965 - 35.2
1959 - 23.3 1966 - 45.3 (tons x 10^3)

Commercial samples and non-official data suggest that prawns are the mainstay of the Gulf of Thailand fishery, which is based on *Penaeus merguiensis*, *P. indicus*, *P. monodon*, and *P. semisulcatus*, together with some *Metapenaeus* spp. and *Metapenaeopsis barbata*, *Parapenaeopsis* spp. and finally *Acetes* spp. inshore.

From the manner in which the catches have been rising in recent years and from surveys such as those by Tiews (1965) it seems likely that although some increase is possible this may well not result in a rise beyond 50.0 x 10^3 tons, which will be used here as the potential of the fishery.

A small fishery for the freshwater *Macrobrachium rosenbergii* and *M. lanchesteri*, and brackish to freshwater species of *Alpheus*, produces about 5.0 x 10^3 tons annually; nothing is known the state of this fishery or of its potential for expansion.

Cambodia

A total of 0.5 x 10^3 tons of miscellaneous crustacea are taken annually, but it is not known what part of this total is formed by prawns; *Penaeus monodon* is known to occur in this catch, however. Status and potential of this fishery is unknown.

Vietnam

Published statistics suggest that catches in southern Vietnam before the present crisis amounted to 29.0 x 10^3 tons annually and catches in the northern part of the country may have been of the same order of magnitude. There appears to be no information as to the composition of the catch but at least in the south it is probably similar to the Thai catch. For present purposes, a potential catch of 50.0 x 10^3 tons is assumed for the whole of Vietnam since there are no data on which to estimate the potential of the resource more objectively.

Chinese People's Republic

"Though no exact figures are available, the Chinese People's Republic is undoubtedly one of the largest shrimp producers in the world" (Ivanov 1964).

Ivanov further suggests that 100.0 x 10^3 tons of prawns are taken annually, of which 70.0 to 80.0 x 10^3 are from the Yellow Sea and are dominated by *Penaeus orientalis* and *Acetes chinensis*. Although the East and South China Sea have a more varied fauna of prawns and shrimps, the Yellow Sea is much more productive commercially.

Most of the production is by small boats at present and probably 90% of all products are consumed by the coastal population, though some is exported to Japan.

For the present purposes, the figure of 100.0 x 10^3 tons perhaps should be retained as the potential of the resource, but an increase by a factor of 1.5 seems very likely with eventual resource management and offshore exploitation, and 150.0 x 10^3 is taken as the potential of the area.

Hong Kong and Macao

Nineteen species of penaeid prawn occur in the Hong Kong catches, and presumably those at Macao are rather similar in composition. The catches seem to be dominated by *Penaeus semisulcatus*,

P. monodon, P. merguiensis, Metapenaeus intermedius and M. affinis.

Latest production figures available for Hong Kong and Macao are for 1965 when 10.4 and 4.0 x 10^3 tons respectively were taken from around 8.0 x 10^3 km^2 of fishing grounds. Although nothing certain is known, it is believed that the catches can be increased, and the potential is thought to be in the region of 20.0 x 10^3 tons.

(iv) The Asian Islands

Philippines

The marine catches are now about 20.0 x 10^3 tons annually, including Penaeus indicus, P. merguiensis, P. monodon, P. semisulcatus (=P. canaliculatus ?), P. esculentus, Metapenaeus ensis, M. burkenroadi and Trachypenaeus curvirostris. Although research is presently being conducted in the Philippines on the rather undeveloped prawn trawl fishery, little information is presently available from it; a catch of at least double the present production would seem attainable, and 50.0 x 10^3 tons is taken as the potential of this sub-region.

As usual in this region, small quantities (production figures lacking) of Macrobrachium lar and related species are taken in freshwater.

Taiwan

A prawn trawl fishery exists in which Penaeus monodon appears to figure rather largely, and for which there are few data beyond the total production which is presently around 14.5 x 10^3 tons (the 1965 figure). Since Taiwan has a much shorter coastline and smaller shelf area than the Philippines there appears to be no justification for supposing that a very great increase in landings might be possible, and the potential increase used here is a very modest 10%, to give a total of 16.0 x 10^3 tons. It should be noted that the shallow, wide shelf areas of Taiwan face westwards towards the Chinese mainland, and any potential here will be shared between the two fisheries.

Japan

The Japanese are major producers of shrimps and prawns, their 1965 catch being in the region of 66.6 x 10^3 tons; a portion of this came from the Northern Pacific (Bering Sea and Gulf of Alaska) and a portion from the Guianas and Australia, outside Region IX. The prawn catch from the Western Central Pacific has declined in recent years; after 1963 it is not possible to separate it in available statistical data from total landings:

1961 - 53.7 x 1.5 = 80.5
1962 - 52.9 x 1.5 = 79.3
1963 - 51.0 x 1.5 = 76.5 (tons x 10^3)

(production statistics are as "heads-off" weights, and a factor is applied above, and throughout this section).

If the known Bering Sea catches are subtracted from the 1965 total it appears that the Western Pacific total by 1965 may have dropped to as low as 55.6 x 10^3 tons, heads-on, but may have been higher than this, there apparently being some confusion in the data.

The bulk of the landings from the Western Central Pacific region are taken in (1) the Inland Sea, and (2) the Yellow Sea.

In the Inland Sea and similar home-island fishing areas Penaeus japonicus forms 25-35% of the catches, but about twice that percentage of their value. Metapenaeus joyneri forms about 20%, the small species Trachypenaeus curvirostris, Metapenaeopsis barbata and Parapenaeopsis tenella about 45%, and the large, valuable species Penaeus monodon and P. semisulcatus about 5%.

The fisheries in the Yellow Sea, the East China Sea and the Korean Bight, which produced about 1.0 x 10^3 tons annually in the early 1960s, are dominated by the oceanic Penaeus orientalis, which occurs in rather deep water, where it is fished by larger shrimp trawlers, especially between November and March.

There are no suggestions in the data now available for review that a potential for increase exists in the Japanese warm-water prawn fishery except in the distant waters of other areas of the Western Central Pacific region. It is likely that any expansion which might be possible in the offshore resources, such as in the *Penaeus orientalis* fishery, might be offset by losses in the nearshore fisheries, especially those of the Inland Sea, due to industrial and agricultural pollution and competition from other uses of these sea areas. A total of 60.0 x 10^3 tons, heads-on, annually is therefore used here as the long-term production to be expected from this area.

(v) Pond production

Pond production of larger species of marine prawns is practiced in several places within the region, and fractionally increase the total prawn production of the region. Recent data on prawns from these sources follow:

Philippines	*Penaeus monodon*	1.0?
Singapore	15 spp. Penaeidae	
Japan*	Various *Penaeus* spp.	
Indonesia	Madura, Java Coastal ponds	
Taiwan	*Penaeus monodon*	
		<10.0 (tons x 10^3)

*Ivanov, 1964, gives 2.0 x 10^3

The data and available information on this form of production show several things rather clearly: that while in some places there are great possibilities for extending pond area and production, in others it is a diminishing resource because of urban and other encroachment (e.g. Singapore); that production is either of high value, preferred species (as in Japan) in which case production sites must be near centres of demand, or of many small species of penaeids, caridians and mysids which are used for biological reduction to paste or for drying; and that production is highest where local populations have a tradition of animal husbandry and pond culture of various fishes, without which its introduction into a new area is probably difficult.

With these limitations, evidently it is not possible to place a limit on the possible expansion of pond cultured prawn production: geographic and economic factors, presently impossible to assess, are limiting and it is now only possible to point to the relatively small proportion this production forms of the total for the region and to indicate that it seems unlikely ever to form more than 10-25% of present production.

Ivanov (1964) and Iversen (1968) give good reviews of prawn culture in this region.

D. Total crustacean potential

The above discussion of the regional production at the present time has been reviewed below; this indicates a total crustacean production of 323.1 x 10^3 tons whole weight annually. This does not correspond with the FAO annual statistics of fisheries because it is compiled from numerous sources, not all referring to the same year; it simply confirms that the total production of crustacea, over and above subsistence level catches which do not enter statistical data bases in most areas, is probably near 350.0 x 10^3 tons annually in this region in recent years.

Using the various projections, which are necessarily of different validity and usefulness, that are used in the preceding discussions, a total production or around half a million tons of crustacea annually seems possible for this region: this may only be an order of magnitude projection, but serves at least to emphasize the great potential of the area. To this figure must be added about 10.0 x 10^3 tons for freshwater production and perhaps 50.0 x 10^3 tons for pond production, giving a grand total of 604.1 x 10^3 tons.

	Present	Potential
Spiny lobsters		
Japan	1.6	
Taiwan	0.1	5.0
Oceania	+	
	(1.7)	(5.0)
Crabs		
Malaysia	1.5	
Thailand	11.0	150.0
Taiwan	1.8	
Japan	≈25.0	
	(39.3)	(50.0)
Prawns (Sea)		
Indonesia	2.5	100.0
Brunei	<1.0	1.0
Sabah	≈3.0	4.0
Sarawak	?	>1.0
Timor/New Guinea	?	>10.0
Australia, Northern Territories	3.0	>20.0
Tahiti	?	>1.0
Tonga, Samoa, Fiji, Guam	+	+
Singapore	0.8	10.0
Malaya	3.4	5.0
Thailand	35.2	50.0
Cambodia	0.5	0.5
Vietnam	50.0	50.0
China	100.0	150.0
Hong Kong/Macao	14.3	20.0
Philippines	20.3	50.0
Taiwan	14.5	16.0
Japan	55.6	55.6
TOTAL	(304.1)	(544.1)
Prawns (Freshwater)	10.0	10.0(?)
(Ponds)	<10.0	50.0(?)
GRAND TOTAL	323.1	604.1 (tons x 10^3)

Region X - Eastern Central Pacific

For the purposes of this review, Region X has been taken to include the western seaboard of the American continent from the northern boundary of California (42°N) to the boundary Ecuador/Peru.

A. Spiny lobster resources

Spiny lobsters of a number of species occur the whole length of the region, but catch statistics are available only for Ecuador (0.3 x 10^3 tons in 1965) and Mexico (1.2 x 10^3), and in the latter case the data refer to both east and west coast catches combined.

In Mexico, a fishery occurs along the Pacific coast of Baja California for *Panulirus interruptus* and *P. inflatus*, and along much of the coast of the Gulf of California and of Sonora and other west coast states for *P. inflatus*; much of this production finds its way to US markets, but statistics on it are meager. It seems certain that increased production is possible, but could not be expected to exceed 5.0 x 10^3 tons annually for the whole of Region X, and this figure, probably too large, will be used as an order-of-magnitude estimate for present purposes.

B. Crab resources

Crabs do not appear in any of the available fishery statistics for the region except in the case of Mexico, and here the catch figures, totalling 1.5 x 10^3 tons in 1965 again include both east and west coasts of the country. It is certain, that as in most tropical regions, the crab resources are under-utilised;many species of portunid swimming crabs occur, some of large size, and (once again) reference should be made to the *Callinectes* production of the eastern seaboard of the USA, in comparison with the very small landings in Region X. It is probable that an increase in production by a factor of at least 10 would be possible, but a more modest estimate based on a factor of only 5 is used here, to suggest that the crab potential of the region may be placed for present purposes at 7.5 x 10^3 tons annually.

C. Prawn resources

About 10 species of penaeids figure in the landing statistics in Region X, and these are listed below. The species composition in the landings is rather constant throughout the region, which is faunistically fairly uniform, having important faunal boundaries to the north and south. Information for Mexico and for Ecuador is not so detailed as for the remaining six countries, but there is no reason to suppose that much of the information relevant to these countries is not also relevant to Mexico and Ecuador. Ivanov (1964) indicates that even in the ecologically unique Gulf of California the important species are among those listed below as being important further to the south.

a) White shrimp - Camaroncillo - *Penaeus vannamei*
- *P. occidentalis*
- *P. stylirostris*

b) Brown or white - Café o blanco - *P. californiensis*

c) Pink or red - Rojo - *P. brevirostris*

d) Seabobs, tiger - Camaroncillo - *Trachypenaeus byrdi*
- *T. similis*
- *T. faoea*

e) Seabobs - Titi ________ ! *precipua*
- *Xiphopenaeus riveti*

Although some mixing among stocks of prawns probably occurs between neighboring countries, especially in Central America, all fishing fleets operate off their own national coasts and the fishing effort in relation to the available resources varies markedly; for these reasons, the data for landings and fishing effort for each country are here kept separate.

Relative abundance of species in the landings may not have any ecological significance: because *P. californiensis* and *P. brevirostris* live relatively deep, they are normally fished for only when shallower-living species are scarce, and the relative abundance of the various species of seabobs in the landings do not necessarily indicate their relative abundance on the grounds. In most fisheries, seabobs are frequenly discarded at sea when prices are not favourable.

Fishing effort is primarily directed at white shrimp (*P. occidentalis*, *P. stylirostris*, *P. vannamei*, plus, in Panama and Costa Rica, *P. californiensis*). Adults of these species have similar ecologies and it is likely that their relative abundance in the landings does, in fact, represent their real abundance on the grounds. Some variation in relative abundance occurs: in Colombia, *Penaeus occidentalis* forms the bulk of the landings, as in Ecuador and Panama, but farther north, in El Salvador, it forms only about 30%. Here and northwards *P. vannamei* attains dominance in the landings.

The shrimp resources show marked local concentrations throughout the region off the mouths of rivers and estuaries, and in muddy bays and gulfs; small fisheries occur in the brackish areas of estuaries, lagoons and embayments but there are no statistical data on these, which seem to be directed at the juvenile stages of several important species of white shrimp, especially *P. vannamei* and *P. stylirostris*.

Landing data for white shrimp are more detailed than for the other groups and in most countries include effort and size frequency information.

and Argentina, to the Antiboreal regions of the south. As might be supposed, the major crustacean resources are those for shrimp in the regions of the major tropical river mouths, particularly in northern Brasil, Surinam and the Guianas, and also in the region of the rather extensive coastal lagoons and estuaries between northern Argentina and southern Brasil.

A. Lobster resources

There is a valuable fishery for spiny lobster, mainly *Panulirus argus* and *P. laevicauda*, along the coast of central Brasil from Belem to Santos; peak catches in recent years were made in 1962 when 4.3×10^3 tons were taken (Bomchi), although the FAO statistics show a rather smaller number (2.9×10^3 tons) for this year. This stock has been the object of international fisheries in some years, having been exploited not only by local boats, but also by French langoustiers fishing for the French domestic market. It is probable that this stock is fairly heavily fished and no great increase in sustainable yield can be expected from it. For present purposes its potential is considered to be 4.0×10^3 tons, or near the present production. Negligible quantities of this species, and of other spiny lobsters, are taken off the coast of Surinam and the Guianas.

B. Crab resources

Rather more than 15.0×10^3 tons of crabs of various species, mostly swimming crabs of the family Portunidae, are taken on the Brazilian coast south of Santos. There are no data on the degree of exploitation of these resources or on their future potential which is here taken to be 20.0×10^3 tons, to reflect the steady increase in production in recent years.

C. Shrimp and prawn resources

The shrimp and prawn resources of this coast which are presently exploited comprise approximately 12 species which are tabulated below. The FAO landing statistics for shrimps and prawns for the east coast of South America indicate clearly that Brasil is the dominant producer followed rather distantly by Guiana.

Guiana - Until 1959, the only production of shrimps in Guiana were from the inshore Chinese shrimp nets which took only small quantities of the very small *Palaemon schmitti* and *Hippolysmata oplotheriodes*. However, in 1959, offshore explorations by US shrimp boats discovered good stocks on the continental shelf of very large penaeids, and the recently increasing production year-by-year is due to initiation of production from these sources. The offshore stocks appear to be dominated by *Penaeus duorarum notialis* and by *Penaeus aztecus subtilis*. The former comprises about 80% of the landings from these stocks, and the latter only about 20%. Production is now probably in excess of 5.0×10^3 tons, and potential is expected to be at least 10.0×10^3 tons annually.

Distribution of known shrimp resources, Region XI; ++ = important stocks, + = less important stocks; A - riverine, B & C - inshore, D - continental shelf, low latitudes, E - continental shelf, high latitudes

		Guiana	Surinam	N. Brasil	S. Brasil	Uruguay	Argentina
A	*Macrobrachium amazonicum*	+	+	+			
	M. carcinus, *et al.*	+	+	+			
B	*Palaemon schmitti*	+	+	+			
	Hippolysmata oplophoroides	+		+			
C	*Xiphopenaeus kroyeri*	++	++	++			
D	*Penaeus schmitti*		+	+	+		
	P. aztecus subtilis		+	++	+		
	P. brasiliensis		+		+		
	P. duorarum notialis			++	+		
	P. paulensis						
E	*Hymenopenaeus muelleri*				+	+	++
	Artemesia longinaris				+	+	++

________ - In this country the situation is rather similar to that in Guiana, and until recent years only inshore stocks of seabobs (Xiphopenaeus kroyeri) were exploited, but more recently continental shelf stocks of penaeid shrimps, which appear to be dominated by Penaeus brasiliensis, have been discovered offshore at around 50 m depth and these have increasingly contributed to the landings as a small fleet of shrimp trawlers has built up. The catches from the continental shelf from Guiana, Surinam and the neighbouring territory of French Guiana have now reached together approximately 6.0 to 7.0 x 10^3 tons annually, and further increases can be looked for. It is quite certain that this production figure can be at least doubled, and a total potential of at least 15.0 x 10^3 tons is postulated here.

Brasil, north of Recife - This includes the rich area of the mouths of the Amazon and other rivers where the continental shelf is wide and all exploratory evidence points to there being extremely rich under-exploited stocks of penaeids. Present production from this region is 10.0 to 15.0 x 10^3 tons annually and is dominated by the small seabob Xiphopenaeus kroyeri, which forms about 60% of the production from this area, and there are indications that very large stocks of larger, commercially interesting penaeids (including Penaeus schmitti and P. aztecus) occur along most of this coastline although they are of course especially concentrated near the mouths of the great rivers. Potential is expected to be relatively high and 25.0 x 10^3 tons seems a conservative estimate.

Brasil, south of Recife - There are two main centres of production of prawns in this area, both of which are probably determined largely by the occurrence of centres of human population rather than for other reasons. In the extreme south from the Doce River to Lagoa de Patos there are active shrimp fisheries off the mouth of the Rio Grande and while in the vicinity of São Paulo shrimp fisheries are again rather active. A number of species of penaeids are taken and these appear to be dominated rather heavily by Penaeus brasiliensis, which certainly dominates the Rio Grande fishery; from January to May the young of this species migrate out of the rivers and estuaries at the peak fishing season. Year-to-year fluctuations are very considerable and appear to be very largely under climatic influence, for in wet years the lagoons are too fresh for the production of large numbers of juveniles and a poor fishery results. The production over the last few years from the Rio Grande fishery is as follows:

1956 - 17.3   1960 - 23.4
1957 - 20.6   1961 - 26.1
1958 - 18.5   1962 - 35.2
1959 - 19.5   1964 - 27.2 (tons x 10^3)

Potential production from this area is postulated here to be equal the highest annual production quoted above; with a modest allowance for the rest of the coast a total of 40.0 x 10^3 is postulated. Fresh-water prawns (Macrobrachium) are, of course, important throughout the Amazon basin and production must be far greater than the 2.6 x 10^3 tons recorded statistically in 1967. It is not possible to guess logically a quantity for total potential production.

________ - The present landings of shrimps and prawns, as of other crustacea from Uruguay, are negligible, though the occurrence of Penaeus paulensis in coastal lagoons in this country and of the northern part of the great estuary of the Rio de la Plata suggest that some potential for expanded production exists; if this occurs, it will in all probability also be based upon Hymenopenaeus muelleri and Artemesia longinaris. A potential of 1.0 x 10^3 tons is used here.

Argentina - There is very little information from the southern area of Argentina, and in the north shrimp catches, mostly of langostino (Hymenopenaeus muelleri) and camaron (Artemesia longinaris) have fluctuated in recent years very widely between 200 and 3,240 tons; these fluctuations are probably caused by fluctuations in spawning success and larval mortality rather than the effect of the fishery which presses rather lightly upon the resources. Surveys in the southern part of Argentina have indicated possibilities for expanded production; in the Patagonian area (particularly in the region of the Gulf of San José) some samples of large ripe females of Hymenopenaeus muelleri have been taken and offer the possibility of a fishery there for this species. There are also indications of the presence of deep water prawns and other crustacea of commercial interest off the coast of southern Argentina at depths around 100 m between 54 and 55°S, and a little further to the north the German research vessel Walther Herwig took commercially interesting quantities of a large species of sergestid shrimp, at depths of from 300-500 m with a mid-water trawl. This ship also took quantities of Campylonotus, Haliticaris and Nephrops in the waters between Buenos Aires Province and southern Brasil and Uruguay. Although these indications are slight and preliminary they do suggest that the occurrence of extensive deep water resources off the southern part of Argentina are at least a possibility. A potential of 5.0 x 10^3 tons is used here for all small natant crustacea. Between 44° and 55°S, Lithodes antarticus is fished off Patagonia and Tierra del Fuego, and catches total about 0.25 x 10^3 tons annually and a potential of 1.0 x 10^3 tons may be assumed.

D. Potential production from Region XI

The present and potential production from this region so far as it can be estimated from present data are indicated below:

	Present	Potential
Lobsters		
Brasil	3.5	4.0
Guianas	+	+
Crabs		
Brasil	15.0	20.0
Argentina	0.8	1.0
Prawns		
Guiana	>2.0	15.0
Surinam	>2.0	
French Guiana	>2.0	
Brasil	30.0-40.0	65.0
Uruguay	0.1	1.0
Argentina	1.0	5.0
TOTAL	>56.4-66.4	111.0 (tons x 10^3)

This suggests that a doubling of present production may be possible and brings the total to about half the production from the Gulf of Mexico and Caribbean to the north; this suggests that the estimate may be too conservative, in consideration of the very great production to be expected off the mouth of the Amazon and the other rivers of northeast South America.

Region XII - Southeast Atlantic

The region extends from the northern border of Angola south through the region of the Benguela Current, and includes the coasts of the Republic of South Africa; to this extent it is an unnatural region as it extends around Cape Agulhas into the Indian Ocean, and includes part of the Indo-Pacific fauna along the coast of Natal.

A. Spiny lobster resources

A number of species of spiny lobsters occur throughout this region and one of them (*Jasus lalandii*) forms the basis of an important fishery in southern Africa. The tropical west African *Panulirus regius* extends from the Gulf of Guinea southward along the northern part of the region and extends just to the southern part of Angola; however, it is nowhere abundant and although small quantities are presumably taken along the Angolan coast it does not appear in the catch statistics, and quantities must be presumed negligible. At Ascension Island and at St. Helena, offshore Atlantic islands which fall within this region, small stocks of *Panulirus echinatus* occur, and although these may have been fished in the past the quantities produced are negligible. Further to the south, at Tristan da Cunha and at Vema Seamount, stocks of *Jasus tristani* occur; the recent discovery of the stocks of this species on Vema Seamount, which is some 500 mi to the northwest of Cape Town has led to the development of a very active fishery there. Production figures for these offshore stocks are not, however, available to the Working Party.

Along the coasts of South West Africa and of the Republic of South Africa between Walvis Bay and Cape Agulhas, there are rather large stocks of *Jasus lalandii* which have been exploited for many years, and which are under strict management control. In the Indian Ocean, along the coast of Natal considerably smaller quantities of the Natal rock lobster *Palinurus gilchristi*, and *Panulirus homarus*. Also some *P. versicolor*, and *P. ornatus* occur. Production figures for spiny lobsters from southern Africa in the last few years are tabulated below.

The management data for *Jasus lalandii* suggests that the stocks of this species around southern Africa are presently fully exploited; evidence from steadily decreasing average size and steadily decreasing catch per unit effort support the supposition that production from known stocks of *Jasus* in southern Africa will not be significantly increased. In fact, in recent years pressure has been brought on the government's quota system for production of *Jasus* by the fishing companies in response to their diminishing returns. The discovery of new grounds, as at Vema Seamount, and the steadily increasing rate of production on the Indian Ocean coast of southern Africa will to some extent help the situation but it is thought that none of these resources will significantly relieve the pressure upon the main stocks of *Jasus lalandii*, which are concentrated to the west of Cape Agulhas.

B. Prawn and shrimp resources

Exploratory fishing off southern Africa for shrimps and prawns in recent years has been relatively profitless through finds of commercial quantities of large penaeid prawns (*Penaeus* sp. and *Hymenopenaeus triarthrus*) were made in depths of almost 250 fm at the edge of the south African continental shelf together with good quantities of a species of *Solenocera*. Also present on these grounds, which are to the east of Cape Agulhas and off Natal, are *Nephrops andamanicus* and the Natal rock lobster. lobster.

Rock lobster production in southern Africa in recent years (tons x 10^3)

	Jasus lalandii		*Palinurus gilchristi*
	South West Africa*	South Africa**	Natal**
1961	-	3.11	0.06
1962	-	3.02	0.07
1963	5.9	3.11	0.08
1964	7.3	3.11	0.18
1965	7.3	3.11	0.28
TOTAL, 1965-10.7			

Notes - * FAO statistics
** S.A. Department of Commerce and Industry Statistics

There are small prawn fisheries already extent along the coast of Natal where, in 1966, about 90 metric tons were landed at Durban, and a few more tens of tons by a group of inshore fishermen at Santa Lucia; however it is assumed that most of the catches landed at Durban have been taken off the coast of Mozambique, which have been discussed with under Region VII. The species involved in the landings at Durban are the following: *Penaeus indicus*, *P. monodon*, *P. japonicus*, *Hymenopenaeus triarthrus*, and *Aristaeomorpha foliacea*; of these, about 70% probably is made up of a single species (*Penaeus indicus*) to judge from the specific composition of the prawn stocks off Mozambique. Lesser quantities, which are often not marketed, of *Metapenaeus monoceros*, *Plesionika martia*, and *Chlorotocus crassicornis* are also taken. *Penaeus indicus* is the most important species taken by inshore fishermen in Natal, with *P. japonicus* second in importance in southern Natal and *P. monodon* and *M. monoceros* about equal and second in importance in northern Natal.

Along the coast of South West Africa north of Walvis Bay as far as the Kunene River there are very abundant stocks close inshore of the small prawn *Macropetasma*, which have been revealed by trawling surveys in this region; however, no commercial exploitation of them appears to have yet occurred.

Towards the end of 1966 a new fishery for prawns and shrimps was developed off the coast of Angola; this was initiated by the arrival of a single Spanish trawler skilled in trawling for deep water prawns in the western Mediterranean out of the port of Huelva. By the beginning of 1968, this vessel had been so successful that a small fleet of 40 trawlers (from 30-50 m overall) had built up in the Angola region, most of them from Spain and principally from the ports of Vigo, Huelva and Cadiz. These vessels are presently making campaigns of about 8 months in the region, and it appears that the annual production now exceeds 1,000 metric tons.

The species of shrimp fished are the gamba, *Parapenaeus longirostris*, the listado, *Aristeus varidens*, and the carabinero, *Plesiopenaeus edwardsianus*. These excellent, large prawns (gamba reach between 9 and 18 cm, listado reach 19 cm and carbinero almost 30 cm) are taken from 6°50'S to 12°S, and in a rather narrow, but deep, depth zone; throughout this region gamba are taken from 250-260 m and the other two from 540-600 m in depth. In this area the slope of the continental shelf is rather steep and the trawlers follow a very narrow band of contours which gives them certain practical problems. It will be noticed by reference to the section upon Region III, and the Mediterranean and Black Seas, that species taken off Angola are identical with species which are also important in the western Mediterranean; this is an expression of the very similar fauna which occurs throughout the tropical Eastern Atlantic at depths below the break of slope on the continental shelf, and which contains very many species in common with the Mediterranean Sea and the coast of western Europe as far to the north as Ireland. In assessing the potential production from this region, it is certainly reasonable to assume an increase in production by a factor of x 2 or x 3 and it seems very probable that the total production of shrimps and prawns between South Africa and Angola inclusive could very easily reach a level of 5.0 x 10^3 tons, which estimate is used here. Also not included in the present consideration are four deep-water penaeids (*Aristaeomorpha foliacea*, *Aristeus varidens*, *Penaeopsis serrata*, and *Plesiopenaeus edwardsianus*) and the pandalid *Plesionika edwardsii* have been reported on numerous occasions as occurring throughout the area but none of these except *Penaeopsis megalops* (which is of small sise) has been located in concentrations sufficient to suggest supporting a commercial fishery. These species, therefore, have not been included in the estimates. The following tabulation summarises the present production of prawns throughout the area by countries, and their estimated potential production. This cannot be broken down by species as in almost every case the available statistics do not permit this.

	Present	Potential
Angola		
Parapenaeus longirostris, etc.	1.0	5.0
S.W. Africa		
Macropetasma sp.	-	1.0(?)
S. Africa		
Natal penaeids	<1.0	1.0(?)
TOTAL	<2.0	7.0 (tons x 10^3)

C. Total potential of Region XII

The data discussed in the text above do not suggest that this region will become a major producer of crustacea in global terms; the tabulation below indicates the likely magnitude of potential production in the foreseeable future.

	Present	Potential
Lobsters		
Jasus lalandii	10.4	10.5
Palinurus spp.	0.3	1.0(?)
Prawns		
Angola	1.0	5.0
S.W. Africa	-	1.0
S. Africa	<1.0	1.0
TOTAL	12.7	18.5 (tons x 10^3)

Region XIII - Southwest Pacific

Region XIII comprises Australia (except W. Australia), New Zealand and its contiguous islands, including New Caledonia and New Hebrides. Exploitation of prawns and crawfish is actively pursued by local fleets, and also by Japanese and Soviet fleets, especially in the tropical northern parts of the region.

A. Spiny lobsters

Various species of spiny lobsters or crawfish are important exploited resources of New Zealand, and of the southern part of Australia.

New Zealand - Southern crawfish (*Jasus edwardsii*) has been under exploitation for many years, by small vessels out of most New Zealand ports, especially those with access to the west coast grounds. Landings in recent years have been:

1962 - 4.6
1963 - 4.6
1964 - 4.6
1965 - 5.0
1966 - 6.6 (tons x 10^3)

For many years the catches have been increasing steadily due mainly to exploitation of fresh grounds on a continuing basis. The sudden increase in 1966 was due entirely to extension of fishing onto the banks around the Chatham Islands, away to the east of the main islands.

Southeast Australia - The southern crawfish (*Jasus novaehollandiae*) is the principal species fished, but others occur, among them the painted crawfish (*Panulirus versicolor*), not presently taken because of its unwillingness to enter pots.

As the following catch statistics show, none of the eastern or southern states enjoy such heavy landings of crawfish as are taken in western Australia (see Region VIII), where *Panulirus cygnus* yields 7.0 to 8.0 x 10^3 tons per year.

Catches in recent years of *Jasus lalandii* off Australia:

	1964–65	1965–66	1966–67
New South Wales	0.2	0.2	0.2
Queensland	+	+	+
Victoria	0.6	0.7	0.7
Tasmania	1.5	1.8	2.0
South Australia	2.7	2.7	2.8
TOTAL	5.0	5.4	5.7 (tons x 10^3)

The slowly rising catches in Australia and the rapidly rising catches in New Zealand, both in fisheries with rather rigid management policies, suggest that in neither place are the stocks fully exploited; in particular, it is likely that the opening of the Chatham Island grounds will further increase New Zealand's catches significantly.

Any catches by foreign vessels in those regions are not available, and any quantification of total potential yields from this region are to this degree uncertain.

B. Crab resources

Small quantities of several species of crabs are taken in Australia, not totalling as much as 1.0 x 10^3 tons, and these catches are ignored here. Future potential of the stocks is entirely unknown. Spider crabs (*Jaquinotia edwardsii*) seem to offer fair prospects around Auckland I.

C. Prawn resources

Between 40 and 50 species of penaeid prawns occur in the region, and of these about 10 are presently useful in the fisheries; many smaller species of shrimps and prawns belonging to other decapod groups also occur, of course, and while some may have local or limited usefulness in the future there are no indications from present data that any will approach the value of the penaeids.

In Australia, exploitation is most complete near the southern and eastern centres of population, and is expanding most rapidly in the under-populated northern regions; off New Zealand, several recent surveys have shown no indication of major prawn resources. A number of species of penaeids occur, and *Nephrops challengerii* has been found in promising quantity in deep water (over 150 fm, 300 m).

Queensland - A trawl fishery operates along the continental shelf from Cairns south to the border of New South Wales, and landings are made in all ports of this area. Five species are exploited: *Penaeus plebejus* (65%), *Metapenaeus bennettae* (16%), and *P. esculentus*, *P. merguiensis* and *M. macleayi* (19%). *P. plebejus* is taken throughout the year, the others during more restricted summer seasons.

Production figures are slowly rising, mainly due to increasing exploitation of oceanic stocks of *Penaeus plebejus*, as tabulated below:

1962 - 2.0 1965 - 2.6
1963 - 2.3 1966 - 2.7
1964 - 2.3 1967 - 2.7 (tons x 10^3)

The future of this fishery is presently unsure, since although a very limited increased production may be possible from the stocks of *P. plebejus*, the stocks of the other species already appear to be overfished.

A set-net fishery in the Moreton Bay rivers of Queensland takes small quantities of *Metapenaeus bennettae*, but this is not separable in the statistics and is included in the figures given above for the trawl fishery, as are the catches from a variety of small-boat trawls and hand-nets in the estuaries and brackish lagoons, where the catch is mainly of *Penaeus plebejus*, *Metapenaeus macleayi* and *M. bennettae*.

New South Wales - The trawl fishery discussed above extends southwards along much of the coast of New South Wales, at least as far as the port of Terrigal, the fleet being dispersed among many of the small ports.

The available statistics for this area do not permit partitioning the catch between the five species involved, which are identical to those in the catches off Queensland. The available data, tabulated below, show that peak production has probably already been achieved in this fishery and no significant increase can be expected from natural resources in the future:

1963 - 2.1 1965 - 2.0
1963 - 3.0 1966 - 1.8
1964 - 2.8 1967 - 1.8 (tons x 10^3)

As in Queensland, catches from the estuarine and lagoon fishery and from a small pocket set-net fishery in lagoon channels, are included in the above data; the same species are exploited as in Queensland.

There appears to be no likelihood that the catches off New South Wales can be increased and present management policies are presumably designed to maintain the present yield; off Queensland, a modest increase is likely, mainly of oceanic *Penaeus plebejus*, but there appear to be no data on which to make a quantified estimate, though a figure between 10% and 20% over present catches seems not unreasonable.

D. Total potential of Region XIII

Only in the case of the tropical shrimp resources of Australia are there any known predictions by local fisheries agencies of the potential size of the catches of crustacea in the region. It seems reasonable to apply subjective, order-of-magnitude extrapolations to fisheries according to the trend of the catches in recent years so as to reach some estimate of the total potential in the whole region. This is done in the following tabulation:

	Present	Potential
Crawfish		
New Zealand	6.6	8.2
S.E. Australia	5.7 (12.3)	6.3 (15.4)
Crabs		
Australia	<1.0 (1.0)	<1.0 (1.0)
Prawns		
New Zealand	-	-
Queensland	2.7	3.1
New South Wales	1.8 (4.5)	1.8 (4.9)
TOTAL	17.8	>20.3 (tons x 10^3)

This estimate of potential catches ignores the possibilities where no fisheries now exist, or where no resource surveys have been performed. It is certain that some potential in tropical crawfish occurs on the offshore reefs of the Queensland coast, and off New Caledonia and New Hebrides, both of which currently report no fishing and no potential for crustaceans. It would probably be safe to add another 5.0 x 10^3 tons for such completely hypothetical resources, raising the grand total for the area to around 25.0 x 10^3 metric tons, in the long-term.

Region XIV - Southeast Pacific

The coasts of Peru and Chile fall within this region; though rich because of strong coastal upwelling, the narrow shelf and the generally rocky nature of the coast is rather unsuitable for the development of great crustacean resources, especially of prawns or shrimps.

A. Crab resources

Lithodes antarcticus has formed the basis of a small fishery in recent years which has shown a modest rate of increase in production, and which now approaches 500 tons per year (see tabulated data below); this is an ecological analogue of the king-crab of the North Pacific (Paralithodes camtschatica) which yielded catches approaching 150.0 x 10^3 tons. Although (i) the shelf area on which Lithodes antarcticus is known to occur is very much less than that for the northern form, and (ii) the southern form averages less than 2 kg against 4 kg for the northern form, it still seems possible that an expansion in this fishery will develop in southern Chile's region of fjords and offshore islands: an increase by a factor of 2-3 seems not unlikely and will be used here, and it is suggested that the potential catch is at least 1.5 x 10^3 tons per year.

Other species (Cancer spp., Taliepus spp., and Homalaspis spp.) of crabs form the basis of a fishery which is presently considerably larger than that for Lithodes, and which yields a little less than 1.5 x 10^3 tons annually in Chile and about 0.2 x 10^3 tons in Peru. There is no evidence to suggest that this fishery is capable of expansion, but in view of the great length of Chile's indented coastline and the present extent to which the fishery is concentrated near centres of population, a factor of 10 is applied for potential producion. It is, therefore, suggested that at least 15.0 x 10^3 tons may eventually be taken by that fishery each year.

Galatheids of two species (Pleuroncodes monodon and Cervimunida johni) support a Chilean fishery which is to some extent complementary to that for prawns. The same vessels fish each stock and the landings of galatheids and of prawns vary inversely. In recent years the catches of galatheids have been ranging from 10.0 to 13.0 x 10^3 tons per year, and it is evident from surveys of the abundance of galatheids on parts of the shelf off Chile and Peru influenced by deposition of material from phytoplankton blooms that an increase of at least a factor of x 5 seems possible. This places the potential catches from these stocks at around 50.0 x 10^3 tons annually. Meat yield is rather low from galatheids, however, and this represents a total of only about 5.0 x 10^3 tons of tails.

B. Spiny lobster resources

Small stocks of spiny lobsters occur, the most important species being Jasus frontalis, which occurs especially at the offshore islands (e.g. Juan Fernandez) but does not seem to occur on the mainland. The data tabulated below shows the small size of this production and suggests that the potential yield may not be much in excess of 0.1 x 10^3 tons per year.

C. Prawn resources

A fishery based on Heterocarpus reedi and Rhincocinetes typus yields about 11.0 x 10^3 tons in Chile and about 0.5 x 10^3 tons in Peru annually. Resource surveys of the grounds on which the species occurs in commercial quantities indicate that these have an extent of 1,600 km², and do not extend below 37°S. The grounds are heavily exploited near ports, but rather lightly farther away from markets, and an increase by a factor of 2 for a total of around 20.0 x 10^3 tons potentially, seems very probable.

A second species, Hymenopenaeus diomedeae, has been surveyed, but is not yet exploited commercially. Occurring rather deeply, at >150 fm, it has not been easy to estimate its potential yield, or the extent of its occurrence satisfactorily. Exploitation will be possible only when production problems imposed by the nature of its habitat are solved, and for present purpose a conservative estimate of 1.0 x 10^3 tons is placed on its potential yield.

Annual rate of production of crustacea by Chile, 1961-66 (tons x 10^3)

	Lithodes	Crabs	Galatheids	Spiny lobsters	Prawns	Barnacles
1961	0.2	1.0	8.1	0.1	2.3	0.5
1962	0.3	0.9	7.9	0.1	4.3	0.9
1963	0.1	0.9	9.2	0.1	3.6	1.5
1964	0.3	1.0	10.6	0.1	5.9	1.0
1965	0.3	1.3	13.3	0.1	5.0	1.5
1966	0.4	1.3	11.3	0.1	10.9	0.9

D. Barnacle resources

Chile is unique in its exploitation of the giant barnacle, Balanus (Megabalanus) psittacus which reached 2.0 x 10^3 tons in 1954, but is lightly fished and market-limited, so that in some recent years only 1.0 x 10^3 tons were taken. It may reasonably be expected to yield 5.0 x 10^3 tons potentially.

E. Total regional potential yield

This may be expressed as:

	Present	Potential
Crabs	14.2	66.5
Spiny lobsters	0.1	0.1
Prawns	11.5	20.0
Barnacles	1.0	5.0
TOTAL	36.8	91.6 (tons x 10^3)

But it must be emphasised that this potential increase, by an overall factor of almost x 3, is based on extremely subjective judgments, and must not be taken in any other light.

GLOBAL ASSESSMENT

The tabulation below summarises the 14 regional assessments presented in the body of the text.

It shows that on the descriptive evidence and on the quantitative data available for this review, the world catch of crustaceans, presently about 1.26 x 10^6 tons, may be expected to rise in the future to almost double this figure, or 2.31 x 10^6 tons annually. This estimate supposes that no 'break-throughs' in harvesting technology which cannot now be foreseen will occur, and that in consequence the resources to be exploited will be similar to those we exploit today.

This final tabulation invites some discussion of the implications it contains of the degree of exploitation of the various resources, and also of the relative validity of the estimates which it comprises.

It is evident from the lack of quantitative data that crab resources, with a few notable exceptions, are either largely ignored, or are treated as of such small importance, that they are lost in statistical 'catch-alls' and recorded only as 'miscellaneous crustacea' or some similar category. It is probably in this general group of resources that both our estimates of present production, and our prognostication of how trends in harvesting will run in the future, are poorest. In the final estimates there is a very large component of subjectivity; the numbers used in this table, however, from the nature of the doubts expressed here, will be minimal and are likely to be exceeded by reality, rather than the opposite.

It is probably also an indication of this data problem, and hence of the great difficulty of making predictions, that makes the apparent percentage increase in production which the table suggests to be rather low.

On the other hand, the quantitative data for all forms of lobster-like crustaceans reflect the high esteem with which these animals are held in world markets. In most cases, the figures used here are rather reliable and the modest size of the increase in production which appears to be possible is probably just a measure of the high intensity of exploitation, and of management, to which stocks of 'lobsters' are already subjected.

The quality of the data which are available for prawns and shrimps is extremely variable: in such places as the Gulf of Mexico and the Eastern tropical Pacific Ocean it is very good, while for some resources (such as the deep penaeids and pandalids) the data are very incomplete, and for several regions (such as the Eastern Indian Ocean) they are very subjective.

Perhaps the two areas of greatest uncertainty in estimations of prawn resources concern the deep red prawns on the upper parts of the continental slope, and the stocks of small, brackish water carideans, especially in the tropics.

Summarised tabulation of present and potential world production of crustacea (tons x 10^3)

Region		Present			Potential		
		Lobsters	Crabs	Prawns	Lobsters	Crabs	Prawns
I	Northwest Atlantic	31.7	2.2	8.6	32.0	10.0	27.0
II	Northeast Atlantic	29.9	13.3	65.4	65.3	20.5	82.8
III	Mediterranean	4.0	+	23.0	4.0	+	50.0
IV	North Pacific	+	208.0	41.1	+	250.0	131.2
V	Western Central Atlantic	13.3	76.9	125.0	21.0	80.0	160.0
VI	Eastern Central Atlantic	2.5	+	4.6	4.0	10.0	63.0
VII	Western Indian Ocean	0.4	+	21.3	3.1	+	144.0
VIII	Eastern Indian Ocean	8.6	+	58.9	10.0	+	98.1
IX	Western Central Pacific	1.7	39.3	304.1	5.0	150.0	544.1
X	Eastern Central Pacific	+	<1.5	65.0	5.0	32.5	75.0
XI	Southwest Atlantic	3.5	15.8	37.1	4.0	21.0	86.0
XII	Southeast Atlantic	10.7	+	2.0	11.5	+	7.0
XIII	Southwest Pacific	12.3	1.0	4.5	14.5	1.0	4.9
XIV	Southeast Pacific	0.1	14.2	11.5	0.1	66.5	20.0
	TOTAL	118.7	372.2, (1.26 x 10^6)	772.1	179.5	641.5, (2.31 x 10^6)	1,492.1

Although prawns of rather a small number of species and genera, typically having rather great areas of distribution, have apparently been found whenever looked for below the continental edge in low and middle latitudes, these are exploited in only three areas; the Gulf of Mexico, the Mediterranean and off Angola. While the Angolan experience in recent years shows that substantial production can be achieved from these resources, there are presently no data on the biological parameters required to judge what sort of sustainable yield may be taken from presently almost virgin stocks. Nor are the survey data elsewhere, for instance in the Eastern Indian Ocean, sufficiently quantitative to compare prospects elsewhere with production in the Mediterranean or off Angola.

The appearance in the production statistics for the western coast of India of 35.0 x 10^3 tons of small caridean shrimps is very surprising in terms of other similar regions. The coast in question is not atypical of tropical regions, but is significantly distinguished by the excellence of the statistical reporting system at the village level, and it must be supposed that similar catches could be (or are) made in parts of the Gulf of Guinea, in the Indonesian and Philippine archipelagoes and along northern Australia. Such suppositions appear to be rather poorly supported by the available quantitative data.

1. PREVIOUS ESTIMATES OF WORLD FISH RESOURCES

1.1 Introduction

A number of authors have made estimates of the world's fish resources. The range of estimates obtained is very wide, and the more conservative figures have been reached and surpassed by the continuing expansion of the total world catch. A comprehensive review of all such published estimates will not be attempted here, but the methods and results will be compared with those used in the present survey. Up to date reviews of earlier estimates have recently been given by Schaefer and Alverson (1968), and Moiseev (1969).

Three broad methods have been used for predicting future catches (c.f. Schaefer 1965):

(a) extrapolation of present trends in total catches;

(b) extrapolation of resources estimates from a known area to the whole world (e.g. Graham and Edwards 1962);

(c) estimation of primary production, and of production at each successive stage in the food chain.

These methods are described in detail below.

1.2 Extrapolation of total catch

This will give much the most accurate estimate of the world catch for the next few years. For the past 20 years the increase in total catch has been remarkably steady, at around 7% per year (see Figure S1). However, the pattern of change in catches from individual fisheries has been very different. The catches from several stocks change little from year to year, and those from many others have oscillated, due to year-class fluctuations or other environmental effects, at about a fairly constant level. These stocks include many of the heavily exploited stocks in the northern hemisphere, e.g. haddock in the North Sea, and on Georges Bank, halibut in the Northeast Pacific, as well as certain species that support the traditional fisheries in tropical and sub-tropical areas.

In contrast, catches from some stocks have increased extremely rapidly. The Peruvian anchovy fishery, in which the catches roughly doubled each year between 1955 (60,000 tons) and 1961 (5 million tons) is the best known and most spectacular example, but is nowhere near unique. Examples include existing fisheries applying the same techniques to new but similar stocks in the same area, e.g. the Norwegian purse seine fleet fishing to supply fish meal factories turned from herring to mackerel, and the Norwegian mackerel catch increased from 20,000 tons in 1963 to 870,000 tons in 1967; the development of new techniques in an area, e.g. in Thailand otter trawling was introduced in 1961, and rapidly replaced the existing pair trawler, catches increasing from 78,000 tons in 1962 to 337,000 tons in 1965 (Isarankura and Kuhlmorgen-Hille 1966); and long-range fleets entering a new area, e.g. catches of hake from the Southeast Atlantic increased from less than 100,000 tons in 1962, taken almost entirely by South Africa to 410,000 tons in 1966, with South Africa lying third behind Spain and USSR.

These very high rates of increase can naturally only be maintained for a limited time, and commonly the period of expansion has ended very abruptly. The development of the Peruvian anchoveta, tabulated below, shows this quite clearly.

Year	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
Catch ('000 tons)	37	43	59	119	326	737	1,909	2,944	4,580	6,275	6,423	8,864	7,233	8,530

	53/4	54/5	55/6	56/7	57/8	58/9	59/60	60/1	61/2	62/3	63/4	64/5	65/6
Increase (%)	16	37	102	174	126	159	54	56	37	2	38	18	18

This sudden end to the period of expansion seems readily explained. Until the catch approaches, the potential yield of the resource, the stock, and hence the catch per unit effort, is not much reduced by the fishery. Also, any slight reduction in stock may be more than balanced by improved techniques, and more experience of the fishery, e.g. knowledge of the best grounds and seasons. Total catches, therefore, increase roughly in proportion to the increase in effort; as the catch per unit

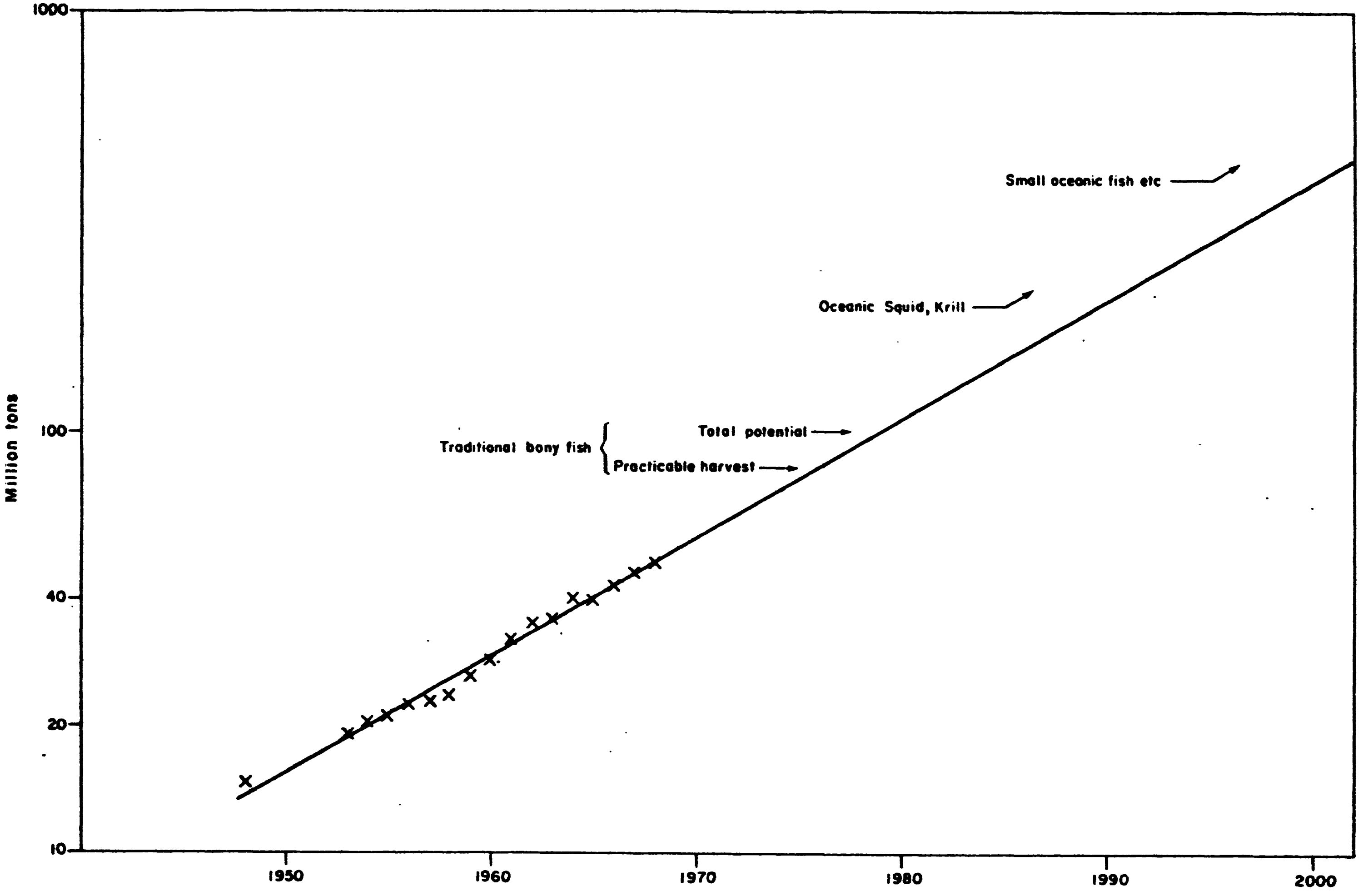


Figure S1 - Trends in world marine fish catch, in relation to the potential of various groups

effort remains high, and demand strong, the incentives to build new vessels, or diverting vessels from existing fisheries, also remain high. Many stocks now support a world-wide market, and therefore, so far as any single stock is concerned, increasing effort and catches will have little adverse effect on price - in fact, through more effective marketing,may help to increase demand, e.g. induce the public to accept South African hake as a substitute for cod. Ultimately, the catches will increase to a sufficiently high proportion of the stock and so reduce appreciably the stock, and the catch per unit effort. The incentive to increase effort will subsequently decrease, or even be removed completely. When the state of harvest has reached this stage, increased effort probably will not increase the total catch.

Prediction of catches from individual stocks by direct extrapolation of recent trends is, therefore, extremely unreliable. Using the Peruvian anchoveta as an example, predictions based on as short a period as three years would have under-estimated the catches in the initial period of expansion, given a good prediction for perhaps three or four years (1960, 1961, 1962 and 1964), and have over-estimated the catch quite severely in 1963 and 1965. Using a period longer than three years would have given even less useful predictions. The operations of long distance fleets provide examples of even less predictable fisheries, e.g. the Japanese and Soviet fisheries for flounders (mainly Limanda aspera and Sebastodes alutus in the eastern Pacific) in the Bering Sea or the USSR silver hake (Merluccius bilinearis) fishery in the Northwest Atlantic.

Prediction of total world catch by extrapolation cannot reasonably be expected to be more reliable in the long run than the prediction of catches from individual stocks, with the exception of the uncertainty in the latter due to the diversion of long-range fleets from one stock to another. Since the latter predictions are highly unreliable, the former is likely to be equally unreliable, at least in the long run. However, as Schaefer (1965) shows, most points for the total marine catch for each year since 1950 plotted in a logarithmic scale fall quite closely on a straight line (see Figure S1) and this line could have been used any time during the past few years to produce a very close prediction of the catch for some years into the future.

This inconsistency arises from the fact that the two predictions (of world catch, and of catch from a particular stock) are, in the short run, concerned with the two different sets of problems. For the individual stock, the vital problems are to determine (a) for unexploited stocks, when will conditions be favourable for the development of the fishery - this will depend on techniques of catching or marketing, results of exploratory fishing, etc., and (b) after development has started, when will the physical limits of production be approached. For the world catch, the immediate questions are whether the drive for further expansion of fisheries will continue; if so, it is probable that favourable conditions will be achieved for development of fishing on some new stocks, and some existing fisheries will approach the limit of their potential. The numbers of each may not vary much from year to year, even though it is difficult to predict for any one year which stocks will be the ones to be developed, and which fisheries cease to expand.

The world situation has been comparable to the expansion phase of a fishery on an individual stock; so long as the total resources have not been greatly affected, and many stocks remain un- or only slightly exploited, the probability of finding new stocks to exploit has remained high and the expansion has continued. If, however, the supply of new stocks begins to run short, then, as for the individual stocks, the falling catches per unit effort on old stocks may no longer be balanced by diversion to new stocks. This may well result in a rapid slowing down in new fishing activities, as fishing ceases to be attractive. The result may be a quite sudden end to the period of expansion, and the beginning of a period when world catches change but little. Perhaps the increase may be no more than 1% per year, as more rational use is made of already exploited stocks.

In this context, new stocks include both stocks of fish of types already exploited in relatively new areas, e.g. hake in the Northeast Pacific, and previously under-exploited stocks, possibly in areas already heavily exploited for other species (e.g. sand-eels in the North Sea). The prediction by extrapolation will only hold good as long as there remain unexploited stocks which can be effectively harvested with existing technology. This clearly was true regarding new areas up to a few years ago, when fish production was concentrated in a few regions; for instance, the fish production in the southern hemisphere was negligible until recently. The distribution of the world catches, by major sea areas, has been set out in Table S1. This gives the percentage of the world catch taken in each area, and also, as a rough guide of the extent of the potential fishing grounds in each area, the percentage of the total shelf area, less than 200 m, and less than 1,000 m (from Moiseev 1969). This shows how the dominance of the Northeast Atlantic, in which one-third of the world's catch was taken in 1948, has disappeared. The previously neglected regions of the Southeast Pacific and Southeast Atlantic are now heavily fished. There are few areas without intense fisheries, either by local or long-range vessels, and exploratory and research vessels are active in most other areas. The period of rapid geographic expansion cannot last very much longer, though development of fisheries on less familiar species may continue. The determination of what the limit to present expansion may be and when it may be reached cannot be made by examination of the trend, but only by analysis of what stocks remain for further exploitation.

Table S1 - Percentage distribution of shelf areas, estimated potential and annual catches by major sea areas

Area	Shelf		Potential	Catches					
	0-200 m	0-1,000 m		1938	1948	1953	1958	1963	1968
Atlantic NW	5.6	5.3	6.4	6.9	9.1	7.5	9.9	8.4	8.3
NE	18.3	16.8	13.2	31.9	36.3	31.2	25.3	19.4	18.2
Mediterranean	1.7	3.1	1.2	3.7	4.0	3.2	2.8	2.2	1.9
WC	5.9	6.2	5.5	4.8	7.9	6.7	3.5	3.1	2.5
EC	2.6	3.0	3.4	1.1	1.6	1.7	2.1	2.4	2.7
SW	9.9	8.8	7.3	0.6	1.1	0.9	1.1	1.2	1.4
SE	1.9	1.9	4.3	0.5	1.6	4.0	3.2	3.6	5.8
TOTAL	45.9	45.1	41.3	49.5	61.6	55.2	47.9	40.3	40.8
Indian Ocean E	6.8	8.3	5.3	3.7	3.4	3.6	3.2	2.1	2.1
W	6.7	6.4	8.8	2.1	2.2	2.1	1.7	1.7	1.8
TOTAL	13.5	14.7	14.1	5.8	5.6	5.7	4.9	3.8	3.9
Pacific N (a)	11.0	10.8	9.7	(17.0)	(14.1)	(12.5)	35.2	29.8	25.6
WC (a)	21.8	19.9	15.9	(23.4)	(14.7)	(24.0)	5.3	6.0	6.7
EC	1.9	2.0	6.0	3.7	2.9	1.3	1.8	1.2	1.3
SW	3.8	5.5	0.6	0.6	0.6	0.4	1.0	0.7	0.7
SE	2.1	2.0	12.4	0.0	0.5	0.9	3.9	18.2	21.0
TOTAL	40.6	40.2	44.6	44.7	32.8	39.1	47.2	55.9	55.3
Northern Temperate (a)	36.5	36.0	30.5	(76.9)	(72.2)	(72.4)	73.2	59.7	54.1
Tropical (a)	45.7	45.7	44.9	(21.4)	(24.0)	(21.4)	18.6	16.6	16.9
Southern Temperate	17.8	18.3	24.6	1.7	3.8	6.2	9.2	23.7	29.0

Note - (a) Boundary between North Pacific and Western Central Pacific was changed between 1953 and 1958. In calculating total temperate and tropical catches, it was assumed that in 1938-53 6% of the world catch came from the Western Central Pacific (new boundaries).

The most valuable use of the trend line and its extrapolation lies in putting a time scale to future development. In particular, after an estimate of the potential yield of fisheries, at least of the present type, has been obtained by other methods, the trend line will show when this potential is likely to be approached. At the corresponding period in the fisheries on particular stocks, when the limited potential from them was approached, crises often occurred. These crises have been limited in severity by their local effect and by the diversion of fishing to other areas and other stocks. An analogous crisis in the fisheries of the world as a whole could be much more severe because of the impossibility of such diversion.

1.3 Extrapolation from known areas

This method depends on obtaining a reliable figure for the potential yield, or rather, yield per unit area, in one region, and applying this figure to the whole ocean, or more usually to the continental shelves. Thus Graham and Edwards (1962) used an average figure of 20 lb/acre (22 kg/ha), and applying this to a figure of 6.0 x 10^9 acres (24.0 x 10^6 km^2) (the estimatedtotal potentially productive area) obtained a figure of 120.0 x 10^9 lb, or 55 million tons for the total world potential.

This figure of 22 kg/ha was based on catches in the late 1950s in the North Atlantic (particularly in the Northwest Atlantic), assuming the stocks on these grounds were fully exploited. Since that time the catches from the areas concerned have increased, though are still below the potential as estimated in the relevant area review of this report. The relevant figures for the ICNAF sub-areas expressed as total catch ('000 metric tons) are set out in Table S2.

Table S2 - Comparison of catches from some Northwest Atlantic grounds in the period considered by Graham and Edwards (1962) with recent catches, and estimates of potential from Chapter A - Northwest Atlantic

Region (ICNAF sub-area)	Average 1956-8		1968		Estimated potential	
	Demersal	Pelagic	Demersal	Pelagic	Demersal	Pelagic
Grand Bank (3)	550	8	982	156	900	900
Nova Scotia (4)	380	100	516	348	900	700
Gulf of Maine (5)	265	100	394	339	700	400
Middle Atlantic (6)	70	470				

Clearly, in the period covered by Graham and Edwards, the grounds were far from being fully exploited, such major stocks as the squid, capelin, herring, sand-eel and silver hake being only lightly exploited, if at all. Their figure of 22 kg/ha should be increased by a factor of three or four to give the true potential of the Northwest Atlantic grounds. This would give estimates of total world potential of 3-4 x 55 = 160-220 million tons, provided the potential per unit area is the same as in the Northwest Atlantic. However, the detailed analysis shows this assumption is not entirely true.

1.4 Estimates from primary production

This method has been used by, among others, Schaefer (1965). Table S3, taken from Schaefer's table, shows clearly how the estimates can be derived. It also shows how critically the actual estimate depends on the trophic level of interest, and also on the ecological efficiency. Using a figure of 19.0×10^9 tons of carbon fixed by phytoplankton, and assuming that carbon was 10% of the live weight, Schaefer obtained estimates of total fish production which ranged from 7.6×10^9 tons at the first stage carnivore level with 20% efficiency, to 19.0×10^6 tons at the third stage carnivore level with 10% efficiency. He considered the potential between the first and second stage carnivore level as being most nearly realistic, giving a production of between 1.1×10^9 and 2.4×10^9 tons, and a potential catch very conservatively of 200 million tons.

Table S3 - Estimated annual production (live weight, million tons) at various trophic levels (from Schaefer 1965)

	Ecological efficiency factor 10%	15%	20%
Phytoplankton (net carbon fixation)	19.0×10^3	19.0×10^3	19.0×10^3
Herbivores	19,000	28,000	38,000
1st stage carnivores	1,900	4,200	7,600
2nd stage carnivores	190	640	1,520
3rd stage carnivores	19	96	304

Using similar arguments, Graham and Edwards (1962) estimated a production at the secondary carnivore level of 1.0×10^9 tons, but considered only 70% of the theoretical transfer at each stage went into useful (to man) channels, and that 1/3 of the secondary carnivore production was in the form of squids, sharks, etc., which they did not consider useful and that only half of the remainder could be harvested without jeopardizing the future of the stock. This gives an estimate of harvestable production of bony fish of 115.0×10^6 tons.

More optimistically, Chapman (1965) considered that 10-15% was too low a figure for the ecological efficiency quoting published results by Lindner and Lasker to the effect that for shrimp and krill (Euphausia pacifica) the conversion rate from food to body weight was about 25%. Using this factor of 25%, he estimated the production of second stage carnivores as 2.0×10^9 tons, which he apparently equates with the potential harvest.

Other authors have obtained results varying within these limits (100.0×10^6 and $2,000 \times 10^6$ tons); most of the variation is due to uncertainties concerning the trophic level at which the harvest is taken, and the ecological efficiency. As Schaefer shows, these can make a very big difference.

One difficulty in this approach is that the potential harvest by man at any given trophic level will be less than the total production at that level. All the production is available for consumption by the next level, of which man may be considered a part, but under natural conditions part of the production will go to the other predators, or be recycled following deaths by disease. Attempts to increase the proportion taken by man by increasing the intensity of fishing will generally tend to decrease the total production of the exploited stock, and may ultimately imperil the future of the resource. The general theories of the dynamics of fish production (e.g. Beverton and Holt 1957) show that the greatest catch is taken with a moderate fishing mortality (probably no more than twice the natural mortality) combined with protection of the smaller fish. Taking into account the natural, non-fishing, deaths before reaching the size at first capture, the potential catch is likely to be no more than half the total fish production. Also fishing will reduce the abundance of a fish population, and hence probably its production, as Gulland (in press) showed for the North Sea demersal fish stocks. The portion of the production of the lower trophic levels no longer used by fish must go somewhere, but may well never appear in a form usable by man.

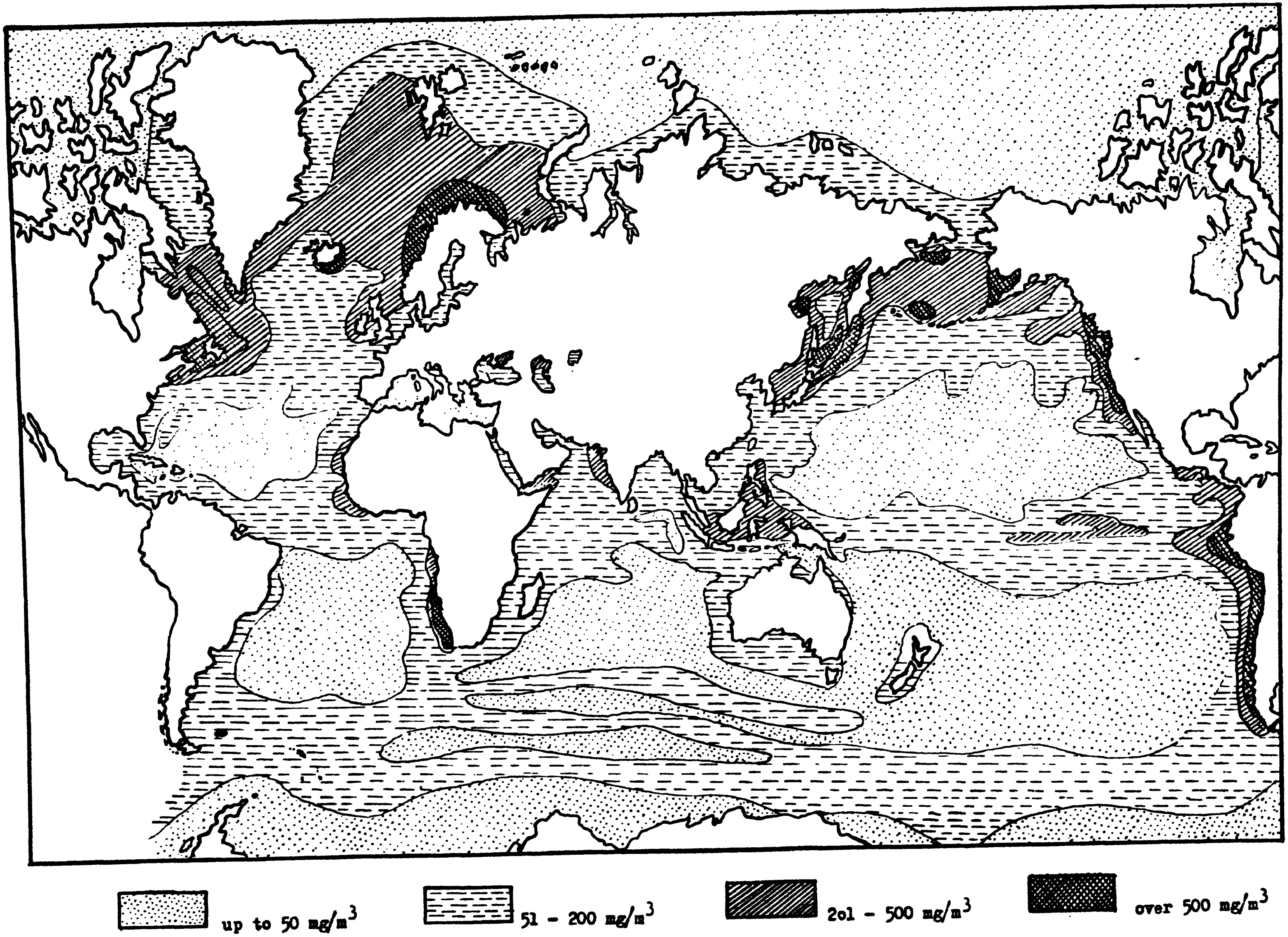
A major difficulty in this approach is the estimation of ecological efficiency. This is generally defined as the ratios of the total annual production at successive trophic levels. It is, therefore, inevitably less than the efficiency of food utilisation (the ratio of growth increment, or production, to food consumed) to the extent that not all production of one trophic level is consumed by the next trophic level, but is side-tracked by disease, etc., ultimately perhaps being recycled via bacteria. Thus the figures of 25% quoted by Chapman should be considered as upper limits rather than valid direct estimates of the ecological efficiency. Also values of efficiency of utilisation may be achieved by fast growing, immature animals, which are much higher than those in the population as a whole, in which old animals may be using most of their food for maintenance.

The ecological efficiency should not be considered as a constant figure. Probably it is higher at the early stages, e.g. between phytoplankton and zooplankton, with the smaller organisms with shorter life-cycles using proportionally more of their food intake for growth rather than maintenance. Fishing may itself affect the efficiency with which the fish population uses its food; by increasing the mortality, the proportion of younger fish in the population, with faster growth and smaller maintenance requirements, is increased. Changes in the species present may also affect the efficiency. Thus, Steele(1965) considered that increases among the North Sea zooplankton of _Calanus_ compared with the smaller _Temora_ and _Pseudo-_ and _Para-calanus_, has permitted more efficient feeding by herring. Therefore, measurements of primary production, plus a single value of the ecological efficiency cannot give very precise estimates of the potential fish catch, though they may be useful in suggesting the order of magnitude.

It is also possible that the ecological efficiency varies in a systematic way from region to region. Thus it has been suggested by Ryther (1969) that the efficiency decreases from 20% in the highly productive upwelling areas to 10% in the open ocean areas with low production. There are very little data to either prove or disprove this suggestion. Blackburn (1966) made a detailed study of standing crops of various trophic levels, in the eastern tropical Pacific. Using a log-log plot, he found highly significant correlations between estimates of standing stock at various trophic levels (chlorophyll, copepods, carnivorous micronekton). The slopes of some regressions were about unity, but he observed that "the standing crop of herbivores generally varies with some power less than 1.0 of the standing crop of phytoplankton.... This implies that herbivores utilise phytoplankton with increasing inefficiency as standing crop of the latter increases". While his observations only apply to one area, and standing crop may not vary with basic productivity in quite the same way as production, Blackburn's observations give no support to the hypothesis that efficiency increases with increasing productivity.

The published estimates of the potential fish catch, using such methods of estimation, still have a wide range, even when allowance is made for these methodological differences. This range is due in a small part to differences in the value used for total primary production, but this is small, and the main uncertainty concerns the ecological efficiency, and the fish species concerned, including their precise position in the food chain. This is shown very clearly in Schaefer's (1965) Table 2. In many areas it is not known either the position in the food-web of the fish species being caught, nor what proportion of the total production at any trophic level is of organisms (fish, squid, whales, etc.) which might be economically harvestable.

Production is greater in the early stages of the food chain, and, therefore, the potential catch is greater if harvesting is carried out at these stages. However, the practical possibilities of actually harvesting at these stages are much more uncertain, depending on the types of animals concerned (which may vary quite markedly from area to area) and the developments in catching, processing and marketing. Technological progress may be expected to make harvesting the earlier trophic levels



Distribution of zooplankton in the oceans in terms of the average volume in the top 100 m
(data from Bogorov et al. 1968)

increasingly more feasible. Thus the potential yield, in any realistic sense, can only be estimated after information is available on the species of animals present, and a decision is made on which types can be considered as likely to be potentially harvestable. In the detailed area reviews these have been, with some exceptions, e.g. krill, taken as being those available to the normal types of gear, especially trawls for demersal fish, lines for the larger fish generally, and gill nets and purse seines for pelagic fish.

Because of these differences of definition, it is probably unfruitful to make further detailed comparison of the varying figures of the world fish potential as estimated from primary production. They have been useful in producing some figures of the likely order of magnitude - between 200 million and 2,000 million tons of fish at the first or second carnivore level.

2. SUMMARY OF REGIONAL STUDIES

The results of the regional studies are summarized in Table S4. The various resources have been grouped into classes, roughly according to the size of the animals concerned - starting with whales, through cods and anchovies, to lantern fishes and euphausids. The accuracy of the estimates decreases in about the same fashion, and in fact totals have only been given for the five first classes - (i) whales; (ii) large pelagic fish (tunas and salmon); (iii) medium to large demersal fish (cods, flounders, sea bream, etc.); (iv) medium pelagic fish (herrings, anchovies, mackerels); and (v) crustaceans. For each group, the world catch in recent years is given. Also for each major area the total potential of the traditional fishes (groups (ii), (iii), and (iv)) and recent catches are given in the table.

The area catches, and potential, have also been summarized in Table S1. This shows that shelf area, potential, and recent catch in each area, as percentages of the world total, are in close agreement. Certain areas - Southeast Atlantic, Eastern Central Pacific, and Southeast Pacific - stand out as being exceptionally productive. These are the areas of major upwelling systems (the Benguela, California, and Peru Currents) for which the area of shelf is a poor measure of the extent and productivity of the potential fishery. One area appears particularly low - the Southwest Pacific. This may be real, but it is an area where data are scanty, and the potential may actually be much higher. No attempt will be made here to produce any correction, but the estimate of the potential in this area should be treated with particular caution.

Table S4 shows how difficult it is to give any meaningful figures for the fish resources of the world. The smallest figure is the total of what might be termed the traditional fish (in the narrow sense, to exclude mammals and invertebrates), i.e. groups (ii), (iii), and (iv), which is very close to 100 million tons. To this should certainly be added some of the later categories, which are already yielding substantial catches. Which of these should be included in a single figure of the living resources of the oceans is rather a matter of subjective opinion, depending on one's views of the economic and technological possibilities of exploiting these resources. Matters of taste and social habits can be very important in determining the price of fish - e.g. squids are heavily exploited round Japan, and southern Europe, where they fetch several hundred dollars a ton as a favoured food, but are only lightly fished off Newfoundland, where they are used mainly as bait at a tenth or less of the price.

At a minimum, any estimate of the ocean resources should include, in addition to the traditional groups mentioned above, the squids in the richer areas where they are abundant, and probably over much of the oceans; also the krill in the Antarctic, and some of the lantern fish and other smaller oceanic fish, at least in the richer upwelling areas. There may well also be resources of larger bony fish not identified in the detailed analyses in those areas, especially the open oceans, for which data are not very extensive. For none of these is any precise estimate available, though a lower limit to the potential of one species of krill (*Euphausia superba*) of 50 million tons has been suggested. Altogether these resources, which are likely to be exploitable on a large scale in, at latest, a few decades, could amount to at least as much as the potential of the more traditional groups, i.e. a total of 200 million tons.

Beyond this, a further range of resources may well be exploitable with major improvements in technology of catching and processing; these will include the small oceanic animals which are too scattered for effective harvesting by present methods. Even copepods may occur in the open ocean in concentrations, detectable by acoustic or other methods, which are not greatly beyond the present level of economic exploitation (Barraclough *et al*. 1969). The best, if very rough, guide to the order of magnitude of such resources is Schaefer's table, at the level of first stage carnivores, i.e. a production of 4,200 million tons for an efficiency of 15%.

Table S4 - Potential yields of various groups of marine animals and recent catches (million tons)

	Northern Temperate					Southern Temperate				Tropical						Antarctic	TOTAL	Catch		
	Atlantic		Pacific		Mediterranean	Atlantic		Pacific		Atlantic		Indian		Pacific						
	NW	NE	NW	NE		SW	SE	SW	SE	WC	EC	W	E	WC	EC			1966	1967	1968
A. Large Pelagic																				
Salmon	ø	ø	0.3	0.3													0.6	0.6	0.6	0.5
Large Tuna, Billfishes)										0.2		0.1		0.4			0.7	0.7	0.7	0.8
Skipjack, Bonito, etc.)					Incl.in tropical areas					0.9		0.6		1.5			3.0	0.7	0.7	0.7
TOTAL	ø	ø	0.3	0.3						1.1		0.7		1.9			4.3	2.0	2.0	2.0
B. Demersal																				
Flounders	0.4	0.8	0.1	0.5	ø	ø	ø										1.8	1.1	1.2	1.2
Cod, Haddock, etc.	1.8	2.9	0.1	0.1													4.9	4.2	4.3	5.0
Hakes	0.6	0.1	-	0.2	ø	1.5	0.6		0.2		ø				0.2		3.4	1.2	1.6	1.3
Small Gadoids	-	1.4	1.5	0.5		1.0	-										4.4	1.8	2.4	3.1
Rock Fishes	0.3	0.3	ø	0.3			ø								0.1		1.0	0.8	0.7	0.6
Croakers, Snappers, etc.	ø	0.1	ø	-			0.2	ø	ø	0.2	0.2	4.4	3.0	11.0	1.1		27.0	10.4	10.8	11.2
Other Demersal	0.5	0.9		0.2	0.4	1.3	0.3	0.2	0.4	1.8	0.7									
Shark, Rays	ø	0.1		ø																
TOTAL	3.6	6.6	1.7	1.8	0.4	3.8	1.1	0.2	0.6	2.0	0.9	4.4	3.0	11.0	1.4		42.5	19.5	21.0	22.4
C. Shoaling Pelagic																				
Anchovies		0.3	0.6	-	0.5	1.0	0.7	0.1	11.0	0.5	0.7	2.0	0.7	1.0	2.5		21.6	10.6	11.7	12.4
Herrings, Sardines	0.7	4.0	0.4	1.0	0.2	1.5	1.4	0.2	0.4	2.0	0.6	1.0	0.5	1.5	0.5		16.1	6.8	6.8	6.8
Mackerel, Jack Mackerel	0.1	1.1	1.4	0.1	0.1	0.5	1.0	0.1	0.2	-	0.4	1.0	0.8	1.5	0.6		8.9	3.2	3.8	4.1
Saury	ø	-	0.5	0.4					0.3						0.1		1.3	0.3	0.3	0.2
Capelin	1.0	0.8	-	0.5		-	-										2.3	0.5	0.5	0.6
Sand-eels	1.0	0.5	0.3	0.5		-	0.1										2.4	0.3	0.3	0.4
Various others						0.5	-			0.5							1.0	1.7	1.7	1.9
TOTAL	2.8	6.7	3.2	2.5	0.8	3.5	3.2	0.4	11.9	3.0	1.9	4.0	2.0	4.0	3.7		53.6	23.4	25.1	26.4
D. Crustaceans																				
Lobsters, Rock Lobsters	ø	0.1	ø		ø	ø	ø	ø	ø	ø	ø	ø	ø	ø	ø		0.2	0.1	0.1	0.1
Shrimps, Prawns	ø	0.1	0.1		ø	0.1	ø	ø	ø	0.2	0.1	0.1	0.1	0.5	0.1		1.4	0.8	0.8	0.8
Crabs	ø	ø	0.3		ø	ø	ø	ø	0.1	0.1	ø	ø	ø	0.2	ø		0.7	0.3	0.3	0.4
Various marine crustns.																		0.1	0.1	0.1
TOTAL	0.1	0.2.	0.4		ø	0.1	ø	ø	0.1	0.3	0.1	0.1	0.1	0.7	0.1		2.3	1.3	1.3	1.4
E. Molluscs	Production largely dependent on cultivation Total potential may be many times that of naturally occurring stocks																			
Oysters	)																	0.8	0.8	0.8
Mussels	)																	0.3	0.3	0.3
Various others																		1.0	1.0	1.1
TOTAL(ex.cephalopods)																		2.1	2.1	2.2
F. Cephalopods																	10-100	0.8	0.9	1.2
G. Lanternfish etc.																	100+			ø
H. Euphausiids																50+	?			
TOTAL A + B + C	6.4	13.3	5.2	4.6	1.2	7.3	4.3	0.6	12.5	5.5	3.4	8.8	5.3	16.0	6.0		100.4	-	-	-
Catch (including crustaceans and molluscs)																				
1966	4.0	10.2	13.2		1.0	0.6	2.2	0.4	10.1	1.3	1.3	1.3	0.8	3.2	0.6			50.2		
1967	4.0	10.2	13.8		1.0	1.3	2.6	0.4	11.2	1.3	1.4	1.2	0.9	3.4	0.7				53.4	
1968	4.7	10.3	14.5		1.1	0.8	3.3	0.4	11.9	1.4	1.5	1.2	1.0	3.8	0.7					56.6

Notes - ø denotes catches less than 100 tons
- information zero

The entries in Table S4 are, even when harvesting is technologically and economically feasible, an upper limit of what can be taken on a sustained basis. Each entry represents the sum of the potentials of a number of separate stocks, and the total potential will only be obtained if each stock is fished at the optimum level.

Even with a good system of management in operation, it is very doubtful if a pattern of fishing could be maintained to exploit all stocks at the proper level. Inevitably some, probably the more valuable, will be to some extent over-exploited, and other - the less valuable, or more dispersed - will be under-exploited. For instance, in the North Sea no specialized fishery for dabs or for gurnards has developed, and only a fraction of the potential of these species is harvested. In practice, no more than perhaps 80% of the total potential in an area may be harvestable because of the difficulties of ensuring the best management of each individual stock. The proportion would be bigger, when the potential is mainly composed of one stock (e.g. Peruvian anchoveta), and less where a range of species are concerned.

If this practical ceiling of 80% is true, then the actual harvest likely to be achieved from the traditional species (groups (ii), (iii), and (iv) of Table S4) amounts to some 80 million tons. This is close to the figure of 73 million tons (29 million tons in addition to the 1966 catches of 44 million tons estimated by Moiseev (1969), though his figure also includes catches of squid, other animals harvested at present but not included in the above groups. Figure S1 illustrates these various levels of potential catch in relation to the actual catches (of marine fishes) that have been taken since 1948. These have been plotted on a logarithmic scale, which shows clearly the remarkably steady rate at which the world catch has been increasing during the last two decades. The figure also shows that, at the present rate of increase, the potential of these groups of fish, called here for convenience, the traditional fish, will be reached around the middle of the present decade. However, if other groups are included, then the present rate of increase of world catch could be maintained for a long period.

Certain conclusions concerning the major problems in world fisheries likely to arise in the near future, can be drawn from this figure. First, as regards the traditional stocks, significant increases in catches cannot be maintained for much longer, and future problems will be mainly concerned with making a rational use of what is available, i.e. the various aspects of fishery management. Second, very large increases in the production of food from the sea can be achieved by turning to less familiar sources, some of which are already being used in some parts of the world. These sources include both the natural production outlined in Table S4 and also the possible production from various forms of aquiculture. The problems for these resources are two-fold - first, obtaining better information on their magnitude and location, and, second, developing more effective methods for their harvesting.

This report is not specifically concerned with the detailed problems of the management of heavily exploited fish stocks, which have been discussed at length in reports and papers from FAO and other sources. However, it may be noted that the progress towards limiting the amount of fishing in international fisheries has been very slow in relation to the speed at which, as shown in the figure, catches from the traditional stocks are approaching their limit. The number of international bodies with responsibility for management has been increasing, until most areas and stocks are covered, but the number of effective international schemes for limiting the amount of fishing is very small. These are mainly restricted to the cases where one country dominates the fishery (e.g. yellowfin tuna in the eastern tropical Pacific), or where only two countries with very similar economics are concerned (Pacific halibut, some stocks of Pacific salmon).

Paradoxically, in view of the later collapse of the industry, the International Whaling Commission may be claimed to have had the greatest success in restricting the amount of fishing in a multi-nation industry. Unfortunately, the restriction was not enough (initially the excess was small) and the biology of whales - particularly their low reproduction rate - is such that even a small excess of fishing beyond the optimum level leads to a progressive decline in the stocks.

Many fish stocks have been able to withstand a relatively greater excess of fishing than that which destroyed the Antarctic whales, due apparently to their much higher reproductive rate, though some other stocks, e.g. Californian sardine have declined to an even greater extent than the Antarctic whales. Fish stocks have also been protected by the mobility of many fishing fleets. As catch rates decline in one area, the fleets can move to a similar, but less heavily exploited stock, elsewhere. This process has been most striking among the long-range fleets, especially from USSR and Japan, during the last decade, but also occurred half a century ago as the centre of the English trawling shifted from the North Sea towards Iceland and the Barents Sea. The number of alternative stocks of the same general type is now becoming exhausted. The problems of achieving, in international fisheries, an effective system of limiting the amount of fishing are, therefore, becoming much more pressing. These may be solved through the existing mechanisms of international commissions, though there are also pressures for more drastic solutions, e.g. by wide extension of national jurisdiction, or by a greater degree of authority, perhaps extending to actual jurisdiction, by some international body.

3. FISH CULTURE

Little mention has been made in the detailed studies of the possibilities of fish culture, except for the culture of molluscs. Though the studies have been restricted to the possible harvest of the natural fish production of the sea, interest in fish culture is increasing, and this culture will undoubtedly have an important influence on the total fish production of the world.

Fish culture may be grouped into two classes - those in which the animals being cultured feed wholly or mainly on the natural production of the water masses in which they are kept, and those in which most of their food is specially provided. Naturally there are graduations between the two classes. For instance, the simpler forms of freshwater fish ponds depend entirely on natural production, but fish yields are increased by a variety of methods of fertilisation and additional feeding until a level is reached at which the supplementary food is the major item in the diet of the fish.

If reliance is placed on natural production, the animals concerned must be plant eaters, or at least very early in the food chain; also to be economically worthwhile cultivating, they must be fairly valuable. For marine animals, this restricts the choice to molluscs, particularly oysters and mussels. The cultivation of these is discussed in Chapter Q - Molluscs.

Fish culture which is not based on the natural production is strictly outside the scope of this study. However, this form of fish culture is already becoming important in some areas, e.g. of shrimp and yellowtail in Japan - and is attracting wide attention as an opportunity for great future developments. If this occurs, large quantities of cheap food will be required, probably with a bigger proportion of fish meal or similar products than is desirable for chicken or pig rearing. This is likely to create a big outlet for the catches of the less well known but abundant marine animals such as krill or myctophids. Thus the practical possibilities of this type of fish culture are very relevant to the probable development in harvesting several of the under-utilised resources.

4. SEAWEEDS

One potential harvest of natural production from the oceans is not considered in detail here, i.e. the seaweeds. A reported total of some 900,000 tons is given as the world's 1968 harvest in the FAO Yearbook of Fishery Statistics, over half of which is taken by Japan. This figure is certainly an under-estimate of the world's harvest, possibly by quite a substantial amount.

Seaweeds are used for a wide range of purposes, mainly industrial, but including direct human consumption of some species, especially in Japan. Since many of these uses are in fields which completely separate from the fields of use of normal fish products, the loss in completeness in not including in the present study of the living resources of the ocean is probably not large. However, a complete study should include them, and studies are in fact now in progress in FAO to this end. It is hoped, therefore, that a detailed section on seaweeds will be included in any future revision of this study. While no quantitative estimate of the potential will be attempted here, it is clear from the geographical distribution of the present catches (over 50% from a small area in the Northwest Pacific), that unless natural production in other parts of the world is very much lower (and standing crop in at least some areas, e.g. southern South America, is high), then the present world harvest could certainly be increased several-fold.

5. FURTHER STUDIES

The figures given in this study, and summarised in Table S4, are clearly only first approximations to the quantities that can be harvested from the various fish stocks of the world. Though it is believed that these approximations are enough to provide useful guides to the development of fisheries, and as warnings of the need for management, it is clear that much needs to be done to make them more precise. Suggestions for further research are given in the individual sections, and may be summarised as follows:

(i) improved statistics;
(ii) further stock assessment studies;
(iii) quantitative studies of standing stocks of unexploited stocks;
(iv) better knowledge of some of the basic scientific problems concerning fish production.

The shortcomings in the statistics have been outlined in the relevant sections; they include (a) poor data on the area of capture by long-range vessels, (b) the catches of small ships and of subsistence and sports fishermen, (c) discards, especially by shrimp trawlers in tropical waters. Another omission in many areas which renders regional studies more difficult is of a regional bulletin of fishery statistics similar to that issued for some 60 years by ICES, giving the total catch in the region by species and sub-area.

The need for further stock assessment studies is obvious. The number of stocks that have been studied in detail (catch and effort statistics, age composition, mortality rates, etc.) is very small. In the last decade, many more stocks have been exploited to the extent that good assessments could be made by established methods. In addition, the simpler models of the population dynamics of marine fish need developing to take into account such things as the possible forms of the relation between parent stock and subsequent recruitment.

Quantitative surveys of fish stocks have generally been confined to trawl surveys, though some use has been made of modern acoustic techniques (e.g. Cushing 1968, Parrish 1969) and egg surveys (Cushing 1957, Saville 1964) to estimate the standing stock of fish. Some general discussion of the problems involved have been made by working groups of FAO (ACMRR(FAO) 1967). With a suitable choice of techniques, it seems that many fish stocks can be surveyed with fair precision and a not unreasonable degree of accuracy. The estimates are, however, normally of standing stock, rather than of production, or possible sustained harvest. One relation between unexploited standing stock (B), and potential harvest (C_{MAX}), has been suggested in the introductory section, viz., $C_{MAX} = 0.5 \times M \times B$, where M is the natural mortality coefficient, but further studies are required to confirm or reject this hypothesis.

Finally, it is clear that very much more needs to be known about the processes of production in the sea. There is a fair amount known about the rate of primary production, and of the production of some of the major commercial fishes, but in between - normally at least one, and possibly several stages of herbivores, primary and secondary carnivores, etc. - very little is known. Even the standing stock is not at all well known for the more active animals such as euphausids, squids and small fish. The biomass of the smaller zooplankton - copepods, sagitta, etc. - is better known, but their position in the food chain is not always well established - some are mainly herbivorous, some carnivorous, and others opportunity feeders.

For all these groups, the relation between standing stock and annual production is unknown. Cushing (1969) divided the standing stock by the estimated generation time to obtain annual production, but this may be an under-estimate. Waters (1969) has shown that for a range of likely patterns of growth and mortality, the total production during a generation is between 2.5 and 5 times the average standing stock.

Another general subject about which far too little is known concerns the ecological efficiency, or the ratio of the production at successive trophic levels. This study is much more difficult in the sea by the fact that few animals fit neatly into a single trophic level. For instance, the Peruvian anchoveta, though at times mainly a phytoplankton eater, at other times eats large quantities of zooplankton (Rojas de Mendiola 1969), and some of these zooplankton animals may themselves be carnivorous for all or part of their life.

Many fish also change their food habits very markedly during their lives. Thus, as it grows, a hake may have as its main food items first zooplankton, then small plankton-eating fish, and then larger fish, including smaller hake; thus it may be separated by successively 1, 2, and 3 stages from the primary production. The trophic level of the hake catch will, therefore, depend on the size of the fish being harvested, and also any estimation of this level will have to take into account that some of the biomass of a large hake will have been produced when it was a small or medium sized fish.

Any estimation of ecological efficiency, under natural conditions, is difficult, if not impossible, due to lack of good data of production other than at the level of primary production, and at the level of the commercial fish. The up-to-date knowledge of this subject was reviewed at a symposium at Aarhus in 1968 (Steele in press). The information available did not suggest that any improvement could at present be made with any confidence to the round figures of 10% or 15% or 20% often used. Higher values of the efficiency of conversion of food into growth were noted, especially at some stages, e.g. among juvenile fast growing copepods, but it was not certain that such high values could be achieved in a natural population. Also the real ecological efficiency would tend to be lower because not all the production at one trophic level will be converted by the next level; against this, the losses, e.g. due to deaths from disease, will tend to be recycled in the system by bacteria without being entirely lost to the productive system.

Despite these uncertainties, a quantitative link has been found in some areas (North Sea, following Steele 1965, and parts of the Northeast Pacific), between primary production and fish production. In the North Sea, at least, the links are strong enough to afford some support to the estimates of fish potential obtained in other ways, and to confirm that no large potential of larger animals has been omitted from the studies. As the basic studies on the productivity at successive trophic levels, and on the transfer between levels, advance, they will certainly enable better estimates of the potential of harvestable animals to be made.

Appendix Table A1 - Recent catches of fish from the Northwest Atlantic (from ICNAF Statistical Bulletin) ('000 tons, live weight)

	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Sub-area 1															
Cod	302	265	321	269	320	234	243	345	451	406	350	359	366	430	353
Redfish	15	32	14	28	18	33	44	54	61	47	30	21	17	13	9
TOTAL	323	305	343	304	346	274	296	417	528	478	413	404	404	465	378
Sub-area 2															
Cod	22	26	34	32	40	60	188	265	255	216	213	333	338	298	406
Redfish	-	-	-	-	77	53	83	26	8	6	27	25	14	17	5
TOTAL	22	26	34	32	119	114	280	297	266	223	261	377	366	329	426
Sub-area 3															
Cod	472	429	392	449	294	425	471	461	389	466	581	498	499	721	743
Haddock	56	104	84	68	44	35	67	79	35	15	12	9	10	11	6
Halibut	1	1	1	2	2	2	3	2	2	1	2	2	1	3	7
American plaice	3(a)	15	14	18	21	21	22	18	17	26	39	50	56	60	55
Redfish	37	18	30	58	159	246	99	90	61	69	95	109	79	89	48
Capelin	-	-	-	7	9	5	6	5	4	5	4	4	4	3	2
Herring	7	5	4	8	11	4	6	4	5	6	3	8	23	79	155
TOTAL	599	591	540	631	555	768	711	694	535	609	784	740	748	1,103	1,157
Sub-area 4															
Pollock	2(b)	19	22	22	29	13	30	29	33	31	32	28	25	15	18
Cod	149	160	198	188	214	214	218	212	219	218	229	225	215	194	247
Haddock	51	43	51	48	49	53	46	47	44	51	60	85	66	49	46
Silver hake	-	-	-	-	-	2	-	-	9	123	81	50	10	2	3
Halibut	2	2	2	3	3	3	3	2	2	2	2	2	1	7	2
American plaice	-(c)	12	9	8	9	9	11	9	7	9	10	15	19	18	19
Other flounders	18(c)	2	2	3	4	4	5	9	9	11	14	22	36	22	52
Redfish	55	59	64	55	55	42	50	42	43	58	53	68	106	88	103
Mackerel	12	11	9	8	7	4	6	4	6	6	10	11	13	11	20
Herring	85	82	78	91	92	102	105	81	116	112	140	181	236	261	348
TOTAL	451	462	511	491	522	524	549	498	578	753	740	777	802	723	940
Sub-area 5															
Cod	12	12	13	13	16	16	14	18	26	30	29	42	57	42	49
Haddock	55	51	59	55	45	41	46	52	59	60	70	155	127	57	44
Pollock	8	10	7	8	14	10	10	8	6	6	9	9	10	9	5
Silver hake	41	46	40	57	49	50	47	43	86	147	221	323	162	101	80
Other hakes	6	6	7	4	4	4	6	5	5	9	31	75	88	45	20
Yellowtail flounder	5	6	6	10	15	13	14	17	26	35	37	37	31	26	33
Other flounders	12	12	14	13	11	12	14	13	13	12	19	20	23	23	21
Redfish	13	14	14	18	16	15	12	14	14	10	8	8	9	11	7
Mackerel	1	1	2	1	2	2	1	1	1	2	2	4	7	16	47
Herring	58	-	66	73	81	48	69	94	223	167	159	74	166	250	337
TOTAL	414	428	470	514	459	459	443	489	693	714	756	890	867	732	810

Notes - (a) Considerable quantities included with various flounders
(b) Considerable quantities included with other groundfish (species not known)
(c) Other flounders include American plaice and witch

Appendix Table A2 - Catches from ICNAF sub-area 6 (from ICNAF Statistical Bulletin)
('000 tons, live weight)

	1966	1967	1968
Silver hake	96	23	15
Red hake	26	15	2
Flounders	9	12	(b)
Other demersal fish	37	20	(b)
Herring	6	5	28
Menhaden	136	122	(b)
Alewife	21	23	(b)
Other fish	24	24	(b)
Total fish	355	244	
Sea scallops	129	27	24
TOTAL (a)	794	645	(b)
USA	639	597	(b)
USSR	131	47	53
Canada	24	1	4
Others	1	1	15

Notes - (a) Includes unspecified shellfish
(b) Full details not available

Appendix Table A3 - Total nominal catch in the ICNAF Convention Area by country (1954-68) ('000 metric tons, round fresh)

Country	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Canada (Maritimes)	357	364	400	410	400	417	529	396	465	504	535	555	638	659	797
Canada (Newfoundland)	325	294	314	289	234	290	294	259	279	297	292	306	336	381	458
Denmark	54	60	58	65	79	79	94	104	138	125	127	121	124	124	97
France	158	143	119	128	128	138	151	180	166	123	160	140	152	159	176
Germany (Fed.Rep. of)	2	22	37	27	71	85	97	174	197	200	149	181	178	217	280
Iceland	18	28	17	23	91	83	40	24	8	12	8	9	7	3	+
Italy	12	10	9	7	3	5	2	4	1	-	-	-	-	-	-
Norway	50	44	43	37	44	32	38	49	36	43	50	44	42	59	80
Poland	-	-	-	-	-	-	-	4	9	23	38	57	72	120	187
Portugal	196	206	225	205	179	160	185	197	218	231	210	197	202	237	219
Romania	-	-	-	-	-	-	-	-	-	-	-	3	3	2	...
Spain	140	161	149	146	123	143	177	208	206	225	230	234	241	290	341
USSR	-	-	17	69	117	182	258	341	370	491	617	853	710	576	741
UK	21	9	5	13	13	18	25	19	27	42	52	56	60	80	47
USA	513	504	541	560	515	501	477	441	482	465	388	350	329	304	286
Others	-	-	-	-	4	11	12	-	-	2	96	93	95	141	...
TOTAL	1,846	1,845	1,934	1,979	2,001	2,144	2,279	2,400	2,602	2,783	2,952	3,199	3,189	3,352	3,712

Notes - ... No data
- Information zero

Appendix Table B1 - Catches of selected species in the ICES area (metric tons)

Species		Areas	1962	1963	1964	1965	1966	1967	1968
Capelin	I	Barents Sea	3,514	34,738	19,675	202,891	279,975	316,957	480,272
	IIa	Norwegian Sea	-	-	-	21,462	109,013	91,410	56,868
		Subtotal	3,514	34,738	19,675	224,353	388,988	408,367	537,140
	Va	Iceland Grounds	-	1,078	8,640	49,735	124,934	97,165	78,166
TOTAL			3,514	35,816	28,315	274,088	513,922	505,532	615,306
Halibut	I	Barents Sea	1,494	2,694	24,083	1,781	1,346	235	257
	IIa	Norwegian Sea	3,378	2,473	2,874	13,707	7,732	2,145	1,910
	IIb	Spitsbergen and Bear Island	828	1,008	2,494	5,137	3,305	12	2
		Subtotal	5,700	6,175	29,451	20,625	12,383	2,392	2,169
	Va	Iceland Grounds	4,924	4,653	3,759	4,060	2,647	2,805	2,091
TOTAL			10,624	10,828	33,210	24,685	15,030	5,197	4,260
Lemon Sole	Va	Iceland Grounds	2,567	2,879	2,352	2,560	1,542	1,418	1,370
	IV	N.C.S. North Sea	4,630	3,791	4,793	5,683	6,134	6,904	6,270
	VII	(VII a + f, b + c, g - k, d + e)	417	271	4,557	5,089	6,468	3,670	753
TOTAL			7,614	6,941	11,702	13,332	14,144	11,992	8,393
Plaice	Va	Iceland Grounds	11,411	9,658	9,368	10,898	11,875	11,380	10,270
	IV	N.C.S. North Sea	87,419	107,062	110,368	96,927	100,130	100,646	108,838
	VII	(VII a + f, b + c, g - k, d + e)	5,170	5,656	7,169	9,069	10,804	11,729	10,876
TOTAL			104,000	122,376	126,905	116,894	122,809	123,755	129,984
Sole (Common)	IV	N.C.S. North Sea	26,841	26,131	11,299	16,966	31,769	21,647	29,400
	VII	(VII a + f, b + c, g - k, d + e)	2,901	2,768	4,164	5,048	3,737	3,711	3,192
TOTAL			29,742	28,899	15,463	22,014	35,506	25,358	32,592
Cod	I	Barents Sea	510,409	508,859	230,844	202,855	264,646	297,204	598,172
	IIb	Spitsbergen and Bear Island	218,041	110,526	75,355	80,139	54,866	113,634	262,832
	IIa	Norwegian Sea	199,346	184,561	162,039	198,399	237,922	208,469	241,436
		Subtotal	927,796	803,946	468,238	481,393	557,434	619,307	1,102,440
	Va	Iceland Grounds	386,422	409,376	434,510	393,552	357,397	343,973	379,457
	Vb	Faroes Grounds	24,230	24,136	25,127	27,127	22,936	26,743	34,150
	IV	N.C.S. North Sea	89,558	105,921	121,550	179,469	219,702	249,803	285,314

Species		Areas	1962	1963	1964	1965	1966	1967	1968
Cod (Cont.)	VI	N.W. Coast Scotland, N. Ireland, Rockall	10,065	14,370	24,137	24,222	18,651	25,210	25,022
	IIIb	c, d, Baltic The Sound and Belt Sea	151,103	146,831	128,111	128,349	158,711	167,806	184,031
TOTAL			1,589,174	1,504,580	1,201,673	1,234,112	1,334,831	1,432,842	2,010,414
Haddock	I	Barents Sea	147,796	111,191	55,833	68,580	75,729	56,164	98,755
	II	Spitsbergen and Bear Island	3,762	1,053	1,169	1,429	1,986	1,101	4,061
	IIa	Norwegian Sea	32,222	33,228	29,906	36,201	51,935	37,810	53,066
		Subtotal	183,780	145,472	86,908	106,210	129,650	95,075	155,882
	Va	Iceland Grounds	119,603	102,562	99,247	99,127	60,141	60,482	51,227
	Vb	Faroes Grounds	27,149	27,569	19,491	18,407	18,762	13,372	17,857
	IV	N.C.S. North Sea	52,419	59,398	198,706	221,700	268,958	167,408	139,469
	VI	N.W. Coast Scotland, N.Ireland, Rockall	10,732	16,864	29,251	33,015	31,816	21,176	21,372
TOTAL			393,683	351,865	433,603	478,459	509,327	357,513	385,807
Hake	VI	N.W. Coast Scotland N. Ireland, Rockall	8,878	8,215	7,909	8,370	6,652	5,827	5,284
	VII	(VII a + f, b + c, g - k, d - e)	21,131	17,320	12,038	33,345	8,435	10,852	8,984
	VIII	Bay of Biscay	46,853	51,752	47,058	17,805	33,003	42,609	42,369
	IX	Portugal Coast	45,355	49,924	57,659	57,017	56,030	55,009	(a)
TOTAL			122,217	127,211	124,664	115,537	104,120	114,297	(a)
Ling	I	Barents Sea	1,094	2,661	1,131	5	11	11	9
	IIb	Spitsbergen and Bear Island	7	14	23	14	3	9	3
	IIa	Norwegian Sea	11,868	6,747	7,059	9,342	5,486	6,496	8,670
		Subtotal	12,969	9,422	8,213	9,361	5,500	6,516	8,682
	Va	Iceland Grounds	12,117	10,492	10,374	10,658	10,032	13,152	14,526
	IV	N.C.S. North Sea	4,512	8,115	10,247	10,024	9,807	7,757	6,349
	VI	N.W. Coast Scotland, N. Ireland, Rockall	4,422	6,449	8,362	8,821	9,010	13,057	16,370
TOTAL			34,020	34,478	37,196	38,864	34,349	40,482	45,927
	IV	Norway Pout	156,960	166,827	82,669	59,342	52,737	180,173	468,713
TOTAL			172,731	185,722	109,720	77,423	??	(a)	(a)
Saithe	I	Barents Sea	10,929	20,809	53,968	16,149	10,479	13,358	15,634
	IIb	Spitsbergen and Bear Island	403	143	994	884	921	275	114
	IIa	Norwegian Sea	109,375	127,675	142,544	168,567	191,575	167,389	94,428

Species		Areas	1962	1963	1964	1965	1966	1967	1968
Saithe (Cont.)		Subtotal	120,707	148,627	197,506	185,600	202,975	181,022	110,176
	Va	Iceland Grounds	50,385	48,449	60,417	60,107	52,168	76,269	77,944
	Vb	Faroes Grounds	10,454	12,693	21,893	22,181	25,497	21,126	20,387
	IV	N.C.S North Sea	22,276	27,571	55,102	68,907	86,927	72,504	97,397
	VI	N.W. Coast Scotland, N. Ireland, Rockall	7,159	6,609	13,596	18,395	18,509	16,034	12,504
TOTAL			210,981	243,949	348,514	355,190	386,076	366,955	318,408
Tusk	I	Barents Sea	807	648	931	423	249	397	605
	IIb	Spitsbergen and Bear Island	100	331	99	55	12	38	70
	IIa	Norwegian Sea	20,096	17,078	20,819	21,432	16,660	17,259	16,229
TOTAL			21,003	18,057	21,849	21,910	16,921	17,694	16,904
Whiting	IV	N.C.S. North Sea	68,967	98,653	91,528	106,694	155,153	91,245	144,920
	VI	N.W. Coast Scotland N. Ireland, Rockall	8,612	10,541	8,612	19,304	18,787	19,709	14,474
	VII	(VII a + f, b + c, g - k, d + e)	26,071	25,756	26,071	27,207	27,207	35,466	29,691
TOTAL			103,650	134,950	126,211	153,205	201,147	146,420	189,085
Redfishes	I	Barents Sea	8,621	10,753	40,030	6,333	6,383	3,655	2,703
	IIb	Spitsbergen and Bear Island	14,746	15,429	11,273	4,467	3,280	1,323	739
	IIa	Norwegian Sea	12,198	15,750	14,874	29,055	25,125	18,653	14,375
		Subtotal	35,565	41,932	66,177	39,855	34,788	23,631	17,817
	Va	Iceland Grounds	75,277	90,132	95,160	113,796	106,627	94,742	96,056
	XIV	East Greenland	27,228	36,838	41,092	36,403	23,191	33,170	23,079
TOTAL			138,070	168,902	202,429	190,054	164,606	151,543	136,952
Sand Eels	IV	N.C.S. North Sea	110,041	162,134	128,501	130,802	161,110	188,795	194,225
TOTAL			110,041	162,134	128,501	130,802	161,110	188,795	194,225
Horse Mackerel	VII	Bay of Biscay	47,204	47,671	51,694	48,507	43,035	48,439	56,393
	IX	Portugal Coast	56,826	69,223	69,690	62,547	53,475	63,851	(a)
TOTAL			104,030	116,894	121,384	111,054	96,510	112,290	(a)
Herring	I	Barents Sea	95,401	93,153	7,869	123,041	174,892	381,036	367,012
	IIa	Norwegian Sea	505,783	622,969	861,664	1,045,845	1,344,894	1,167,032	282,685
	Va	Iceland Grounds	650,508	507,703	625,141	624,040	482,615	118,014	30,775
	Vb	Faroes Grounds	6,618	23,060	14,514	4,391	8,618	27,016	6,019
	IV	N.C.S. North Sea	678,515	805,301	932,046	1,230,315	1,038,851	819,324	850,127
	VI	N.W.Coast Scotland N. Ireland, Rockall	63,699	53,949	69,720	66,385	93,147	103,074	100,323

Species		Areas	1962	1963	1964	1965	1966	1967	1968
Herring (Cont.)	VII	(VII a + f, b + c, g - k, d - e)	37,226	29,543	20,753	23,385	38,306	40,166	41,525
	IIIb,	c, d Baltic, The Sound and Belt Sea	177,045	214,852	216,001	214,916	232,709	267,224	315,652
	IIIa	Kattegat and Skagerrak	116,771	159,988	273,603	238,923	152,449	244,698	288,987
TOTAL			2,331,556	2,510,518	3,021,311	3,571,241	3,566,481	3,167,584	2,283,105
Pilchard	VIII	Bay of Biscay	51,440	49,141	47,139	39,543	37.566	38,536	32,205
	IX	Portugal Coast	176,617	170,546	204,191	184,798	168,985	160,291	(a)
TOTAL			228,057	219,687	251,330	224,341	206,551	198,827	(a)
Sprat	IV	N.C.S. North Sea	31,312	67,668	70,812	76,180	106,577	69,496	65,437
	III	b, c, d Baltic, The Sound and Belt Sea	62,732	61,045	80,818	73,598	70,254	61,487	74,065
TOTAL			94,044	128,713	151,630	149,778	176,831	130,983	139,502
Tunas	VIII	Bay of Biscay	54,674	47,658	51,834	50,743	40,689	51,768	40,629
	IX	Portugal Coast	10,887	18,090	10,305	14,281	14,064	10,569	(a)
TOTAL			65,561	65,748	61,139	65,024	54,753	62,337	(a)
Mackerels	IV	N.C.S. North Sea	66,285	55,402	79,390	151,721	505,134	909,879	808,578
	IIIa	Kattegat and Skagerrak	12,747	17,666	35,607	56,745	24,594	20,069	12,867
		Subtotal	79,032	73,068	114,997	208,466	529,728	929,948	821,445
	VII	(VIIa + f, b + c, g - k, d - e)	20,230	24,560	22,778	16,562	41,205	33,518	34,728
	VIII	Bay of Biscay	12,368	15,871	16,923	21,627	25,881	33,702	25,898
	IX	Portugal Coast	18,729	10,713	11,776	34,140	18,244	22,219	(a)
TOTAL			130,359	124,212	166,474	28 ,795	615,058	1,019,387	(a)
Dogfishes	IV	N.C.S. North Sea	30,437	34,366	21,638	26,108	23,414	26,346	36,416
	IIa	Norwegian Sea	6,797	4,850	3,527	2,418	1,593	1,368	1,374
TOTAL			37,234	39,216	25,165	28,516	25,007	27,714	37,790
Rays & Skates	IV	N.C.S. North Sea	9,588	10,683	10,982	10,037	8,233	7,474	7,702
	VI	N.W. Coast Scotland, N.Ireland, Rockall	3,714	3,910	4,787	4,317	3,905	3,819	3,753
	VII	(VII a + f, b + c, g - k, d + e)	21,765	21,994	21,344	17,641	16,019	16,740	17,275
	VII	Bay of Biscay	6,862	5,920	6,732	5,921	5,787	5,769	6,052
TOTAL			41,929	42,507	43,845	37,916	33,944	33,802	34,782

Species	Areas		1962	1963	1964	1965	1966	1967	1968
Unsorted	IV	N.C.S. North Sea	23,100	49,564	154,034	136,127	56,523	56,262	57,636
	VII	(VII a + f, b + c, g - k, d + e)	29,788	33,794	33,393	37,757	22,816	2,001	25,457
	VII	Bay of Biscay	28,517	28,580	35,321	15,670	30,485	13,718	32,234
	IX	Portugal Coast	36,731	46,441	49,291	36,731	47,712	54,372	(a)
TOTAL			118,136	158,379	272,039	226,285	157,536	126,353	(a)

Note - (a) Data not yet available

Appendix Table B2 - Catches by sub-areas in the ICES area

		1962	1963	1964	1965	1966	1967	1968
1 **Barents Sea**	**Pelagic**	132,734	129,589	28,882	326,572	459,936	704,020	852,570
	Demersal	718,346	681,362	427,994	313,894	383,942	390,808	739,608
TOTAL		821,080	810,951	456,876	640,466	843,878	1,094,828	1,592,178
II **Norwegian Sea**	**Pelagic**	510,775	625,167	862,355	1,073,757	1,460,079	1,261,139	343,531
	Demersal	426,660	418,872	422,796	518,385	581,311	513,803	460,916
TOTAL		937,435	1,044,039	1,285,151	1,592,142	1,041,390	1,774,942	804,447
IIb **Spitsbergen and Bear Island**	**Pelagic**	2,228	1,044	1,320	1,426	1,476	80,961	53,801
	Demersal	245,793	135,066	93,565	94,090	66,504	123,681	281,048
TOTAL		248,021	136,110	94,885	95,516	67,980	204,642	334,849
Total(I + IIa + IIb)	**Pelagic**	615,737	755,800	892,557	1,401,755	1,921,491	2,046,120	1,249,902
	Demersal	1,390,799	1,235,300	944,355	926,369	1,031,757	1,028,292	1,481,572
TOTAL		2,006,536	1,991,100	1,836,912	2,328,124	2,953,248	3,074,412	2,731,474
Va **Iceland Grounds**	**Pelagic**	657,406	514,386	643,366	683,240	615,413	219,905	115,510
	Demersal	707,496	730,594	754,304	734,638	637,336	661,850	680,915
TOTAL		1,364,902	1,244,980	1,397,670	1,417,878	1,252,749	881,755	796,425
XIV **East Greenland**	**Pelagic**	424	1,169	1,895	1,562	42,724	229	223
	Demersal	46,216	62,369	79,696	57,019	37,299	59,350	40,173
TOTAL		46,640	63,538	81,591	58,581	80,023	59,579	40,396
Total(Va + XIV)	**Pelagic**	657,830	515,555	645,261	684,802	658,137	220,134	115,733
	Demersal	753,712	792,963	834,000	791,657	674,635	721,200	721,088
TOTAL		1,411,542	1,308,518	1,479,261	1,476,459	1,332,772	941,334	836,821
Vb **Faroes Grounds**	**Pelagic**	7,867	24,417	15,661	5,335	10,368	27,380	8,033
	Demersal	77,431	80,712	91,683	92,982	85,863	82,981	98,698
TOTAL		85,298	105,129	107,344	98,317	96,231	110,361	106,731
IV **N.C.S. North Sea**	**Pelagic**	919,640	1,145,780	1,367,575	1,733,169	1,871,524	2,048,613	1,978,250
	Demersal	590,876	690,258	773,900	858,801	1,010,652	977,204	1,368,317
TOTAL		1,510,516	1,836,038	2,141,475	2,591,970	2,882,176	3,025,817	3,346,567
VI **N.W.Coast Scotland, N.Ireland, Rockall**	**Pelagic**	72,051	60,462	79,017	75,883	101,403	108,933	112,757
	Demersal	64,620	79,931	127,167	133,378	125,386	123,837	116,995
TOTAL		136,671	140,393	206,184	209,261	226,789	232,770	229,752

Species		Areas	1962	1963	1964	1965	1966	1967	1968
Pelagic	III	Baltic, The Sound and Belt Sea, Kattegat and Skagerak	72,051	60,462	79,017	75,883	101,403	108,933	
Demersal			270,026	254,496	237,475	223,087	251,347	278,739	299,504
TOTAL			744,103	819,069	885,821	847,904	783,335	926,862	1,039,635
Pelagic	VII	(VIIa + f, b + c, g - k, d + e)	96,080	100,303	94,626	89,890	109,903	81,819	112,066
Demersal			121,386	123,245	140,803	171,484	144,835	154,581	144,591
TOTAL			217,466	223,548	235,429	261,374	254,738	236,400	256,657
Pelagic	VIII	Bay of Biscay	268,217	250,066	296,831	301,412	238,403	237,552	243,104
Demersal			120,088	136,428	138,027	115,552	129,095	139,513	148,013
TOTAL			388,305	386,494	434,858	416,964	367,498	377,065	391,117
Pelagic	IX	Portugal Coast	343,431	343,194	379,109	388,986	349,392	354,942	(a)
Demersal			66,903	71,938	78,069	81,681	80,671	80,355	(a)
TOTAL			410,334	415,132	457,178	470,667	430,063	435,297	(a)

Notes - For the purpose of this table, Demersal and Pelagic are defined in terms of the FAO species groups. Demersal includes all flounders, cods, redfishes, etc. (except sand-eels) and sharks. Pelagic includes capelin, sand-eels, herrings, jacks, tunas, mackerels, and unsorted.

(a) Data not yet available

Appendix Table B3 - Total catch in ICES area by FAO species groups

Species	1962	1963	1964	1965	1966	1967	1968(d)
Demersal Total	3,518,246	3,538,541	3,380,314	3,418,722	3,539,769	3,700,000(c)	4,454,834
Flounders	279,724	289,341	312,149	299,504	310,996	326,248	322,442
Cods	2,855,359	2,842,772	2,632,025	2,706,469	2,857,537	2,901,145	3,769,070
Redfishes etc (a)	265,446	282,138	314,693	311,682	272,662	259,391	266,822
Sharks	117,717	124,290	121,447	101,067	98,574	114,676	96,500
Pelagic Total	3,485,585	3,780,025	4,445,866	5,329,183	5,813,053	5,534,527	4,657,981
Capelin	3,768	35,816	28,315	274,088	513,937	505,638	615,771
Jacks, Mullets	120,015	138,486	151,304	142,502	114,699	63,597	83,489
Sand-eels	140,105	184,234	132,038	140,989	180,635	209,890	201,221
Herrings	2,784,768	2,960,083	3,559,989	4,099,691	4,107,408	3,700,000(c)	2,630,468
Tunas	75,454	66,384	68,946	76,175	60,921	64,550	52,176
Mackerels	157,223	143,266	182,297	297,638	627,167	1,025,000(c)	897,175
Unsorted	204,252	251,756	322,977	298,100	208,286	118,764	177,681
Crustaceans (b)	126,950	151,468	134,639	124,959	128,907	118,623	122,216
Molluscs (b)	262,238	243,490	292,327	307,068	390,751	274,627	401,555
GRAND TOTAL	7,003,831	7,318,566	7,826,180	8,747,905	9,352,822	9,390,000(c)	9,112,815

Notes - (a) Except sand-eels
(b) Not included in total
(c) Estimated
(d) Grand total does not include data for Portugal as not available

Appendix Table C1 - Catches in the Mediterranean and Black Sea by countries ('000 metric tons)

Country	1960	1961	1962	1963	1964	1965	1966	1967	1968
Albania				3.5	3.6	4.0	4.0	4.0	4.0
Algeria				16.9	17.3	18.2	20.3	21.0	18.2
Bulgaria(a)				7.5	13.2	19.8	26.8	21.8	36.3
Cyprus				0.6	0.6	1.0	0.9	0.9	1.4
France				31.2	34.1	27.5	35.0	48.9	48.9
Gibraltar				...	...	...	...	...	...
Greece				84.9	84.1	55.3	52.8	53.5	55.0
Israel				2.5	2.7	2.9	2.8	2.6	3.3
Italy				255.6	269.9	280.9	288.0	286.9	283.8
Lebanon				2.2	2.0	2.3	2.5	1.8	2.5
Libya				0.1	0.5	2.9	3.3	4.2	5.5
Malta				1.6	1.4	1.2	1.3	1.4	1.6
Monaco				...	...	...	...	...	...
Morocco				6.3	8.6	8.3	9.2	7.4	10.0
Romania				6.7	4.5	8.4	3.8	4.1	4.2
Spain				120.9	120.9	111.7	108.4	106.4	111.7
Syria				0.5	0.5	0.5	0.6	0.7	0.8
Tunisia				25.8	21.4	22.8	25.8	33.1	35.0
Turkey				123.4	114.6	129.1	114.0	176.2	127.6
UAR				32.9	26.0	24.7	15.0	15.0	15.0
USSR				203.0	226.4	238.0	290.5	278.3	263.1
Yugoslavia				21.3	25.3	26.0	27.3	30.0	29.9
TOTAL *				950.0	980.0	990.0	1,030.0	1,100.0	1,060.0

Notes - ... No data

* Includes estimates for the catch data of countries where "..." indicate that no official figures are available to FAO. Total is rounded to the nearest ten thousand metric tons

(a) Includes freshwater. Catches in the Black Sea average 4,400 tons in 1960-9, 90% being pelagic species

Appendix Table C2 - Catches in the Mediterranean and Black Sea: by group of species and by species ('000 metric tons)

Group of species Species	1960	1961	1962	1963	1964	1965	1966	1967	1968
Shads				25.0	52.0	83.0	96.0	89.0	60.0
Flatfishes				10.0	10.0	11.0	10.0	9.0	9.0
Sole (common)				5.0	4.2	5.7	4.6	3.8	3.6
Gadoids				26.0	29.0	26.0	28.0	28.0	30.0
Hake (European)				13.8	13.3	13.4	15.3	15.1	15.1
Redfishes, basses, congers, etc.				93.0	124.0	124.0	132.0	129.0	120.0
Jacks, mullets, etc.				80.0	64.0	56.0	60.0	87.0	72.0
Horse mackerels				50.5	38.8	31.2	34.6	54.9	42.2
Mullets				10.2	10.9	10.8	11.9	17.1	14.7
Clupeoids				333.0	325.0	320.0	383.0	382.0	398.0
Anchovy (North Atlantic)				205.9	203.2	202.3	240.5	263.9	265.8
Pilchard (European)				112.0	108.4	101.1	122.3	109.0	120.8(a)
Tunas, bonitos, skipjacks				29.0	22.0	34.0	30.0	53.0	36.0
Bluefin tunas				3.9	5.0	4.1	4.4	8.4	6.4
Atlantic bonito				20.5	13.5	25.2	20.6	38.6	24.6
Mackerels, etc.				40.0	33.0	36.0	28.0	28.0	30.0
European mackerel				30.8	28.0	27.8	23.6	20.6	22.7
Sharks, rays, chimaeras				11.0	11.0	15.0	15.0	23.0	19.0
Unsorted and unidentified fishes				171.0	174.0	154.0	125.0	138.0	151.0(a)
Crustaceans				31.0	34.0	30.0	29.0	29.0	29.0
Molluscs				92.0	91.0	94.0	86.0	98.0	97.0

Note - (a) Aggregates of which more than 10% was estimated by FAO

Appendix Table D1 - Total catches in the North Pacific, 1962-7 ('000 tons)

Country	1962	1963	1964	1965	1966	1967
Canada	293.8	318.3	314.3	322.0	286.4	160.2
Japan	2,550.0	2,330.0	2,350.0	2,550.0	2,550.0	3,500.0
Korea (South)	140.4	157.9	179.0	189.6	202.2	214.5
Korea (North)	250.0	250.0	250.0	250.0	250.0	250.0
USA	320.9	314.8	334.7	350.9	397.9	233.2
USSR	1,083.9	1,212.6	1,438.6	1,589.0	1,633.7	1,771.2
China (Mainland)	250.0	250.0	250.0	250.0	250.0	250.0
TOTAL	4,889.0	4,833.6	5,116.6	5,501.5	5,570.2	6,369.2

Note - The division of the catches of Japan between the North Pacific and the Western Central Pacific has been estimated (see also Appendix Table I1)

Appendix Table D2 - Catches of some major species from the North Pacific ('000 tons) (a)

Species	Country	1964	1965	1966	1967	1968
Various flounders	Japan (b)	177	126	85	104	94
	USSR	139	100	137	178	105
Pacific cod	Japan	95	90	86	96	109
	USSR	5	6	6	10	22
TOTAL		110	114	110	118	142
Alaska pollack	Japan	684	691	775	1,247	1,606
	Korea (Rep.of)	21	27	21	18	29
	USSR	214	324	425	471	567
TOTAL (c)		(918)	(1,042)	(1,221)	(1,735)	(2,201)
Pacific herring	Canada	229	201	140	53	3
	Japan	57	50	49	64	68
	USSR	460	331	323	342	445
TOTAL		770	599	522	467	523
Japanese pilchard		16	9	14	17	24
TOTAL		16	9	14	17	24
Japanese anchovy	Japan	296	406	408	365	358
	Korea (Rep.of)	36	57	66	79	63
TOTAL		342	473	486	456	430
Rockfishes	Japan	77	108	128	133	147
	USSR	276	392	248	171	85
TOTAL		373	525	401	323	252
Atka mackerel	Japan	205	107	106	82	82
	Korea (Rep.of)	7	7	4	4	26
TOTAL		212	115	111	86	113

Notes - (a) For estimated catches in the Northeast Pacific, see Appendix Tables E1-E3
(b) Mostly yellowfin sole (Limanda aspera)
(c) Omitting catches by North Korea, approximately 250,000 tons in 1964
Brackets denote approximation

Appendix Table E1 - Total catches of salmon from North Pacific ('000 metric tons)

Species	1961	1962	1963	1964	1965	1966	1967	1968
Chinook	17.0	17.1	18.1	21.9	21.1	21.5	19.8	18.9
Chum	108.0	114.3	104.4	119.7	97.4	123.0	126.8	137.3
Coho	29.7	36.9	40.1	44.0	44.6	43.0	31.9	35.7
Pink	178.0	164.0	209.0	144.0	161.0	175.0	169.0	137.0
Sockeye	103.6	65.5	47.6	53.8	104.2	78.6	49.9	46.3
TOTAL	436.3	397.8	419.2	383.4	428.4	441.1	397.4	375.2

Appendix Table E2 - Demersal catches from the Northeast Pacific ('000 metric tons)

Species	Country/Area	1961	1962	1963	1964	1965	1966	1967	1968
Yellowfin flounder	Japan - Bering Sea	457	351	66	102	43	46	58	
	USSR							120	
Halibut	Canada	18	21	22	20	20	20	17	19
	Japan	8	8	7	2	1			
	USA	24	24	21	16	18	18	18	12
Other flounders	Japan - Bering Sea	(a)	(a)	(a)	(a)	(a)	22	34	
	Japan - Gulf of Alaska	-	-	+	(1)	(3)	5	6	
	Canada	3	3	3	3	3	5	4	5
	USA			23	21	21	21	21	21
Pacific hake	USA	+	+	+	+	1	5	13	7
	USSR						128	167	104
Pacific cod	Canada	2	2	3	5	10	11	6	6
	Japan - Bering Sea	7	11	16	19	16	17	31	
	Japan - Gulf of Alaska	-	-	+	+	+	1	3	
	USA	1	1	3	3	5	4	4	3
Alaska pollock	Japan - Bering Sea	24	62	114	175	231	264	546	
	Japan - Gulf of Alaska	-	-	+	(2)	(5)	8	8	
Sable fish (Black cod)	Canada					+	1	+	+
	Japan - Bering Sea	26	28	21	7	3	6	7	
	Japan - Gulf of Alaska	-	-	+	(1)	(2)	4	6	
	USA			3	4	3	3	3	3
	USSR							1	
Pacific Ocean perch	Canada					2	3	1	
	Japan - Bering Sea	13	14	25	45	46	45	25	
	Japan - Gulf of Alaska			(8)	(15)	(40)	66	76	
	USA					13	10	7	6
	USSR							174	
TOTAL, all demersal species	Canada					37	42	34	
	Japan - Bering Sea	555	697	260	367	340	433	739	
	Japan - Gulf of Alaska			9	20	54	85	107	
	USA					57	60	59	
	USSR							535	
TOTAL, all countries								1,477	

Note - (a) Japanese statistics from INPFC

Brackets denote approximation

Appendix Table E3 - Total catches from the Northeast Pacific ('000 metric tons)

Species		1961	1962	1963	1964	1965	1966	1967	1968
Demersal fish	Total							1,477	
Salmon	Total (a)	436	398	419	383	428	441	397	375
Herring	Canada	203	202	260	229	201	140	53	3
	Japan	74	10	32	43	36	28	33	...
	USA	25	19	18	24	16	11	8	6
King crab	Japan (a)	28	34	32	32	26	31	30	30
	USA	20	24	36	39	60	72	58	39
	USSR (a)	39	41	42	46	44	46	42	40
Shrimp	Canada	1	1	1	1	1	1	1	1
	Japan	14	21	32	20	9	3	3	...
	USA	10	10	10	7	9	16	25	24
Molluscs	Canada	4	5	7	6	6	7	6	4

Notes - (a) Total North Pacific

... No data

Appendix Table F1 - Catches in the Eastern Central Atlantic by countries ('000 metric tons)

Country	1958	1961	1962	1963	1964	1965	1966	1967	1968
Cameroon	2.8	3.7	5.3	6.6	7.0	8.5	9.0	10.9	12.6
Cape Verde Islands (a)	1.7	1.6	1.5	2.0	2.5	3.5	4.0	5.9	4.9
China (Taiwan)	-	-	-	-	0.1	0.2	1.5	0.3	6.9
Congo (Brazzaville)	...	5.6	8.6	8.5	9.6	11.0	11.2	10.6	11.1
Congo (Dem.Rep. of)	5.1	7.0	7.0	9.5	10.0	11.0	12.0	12.4	12.4
Dahomey	3.0	6.0	6.0	3.0	4.0	4.0	3.8	5.6	5.6
Equatorial Guinea	0.1	0.5	0.8	1.0	1.0	0.6	1.2	1.0	1.0
France	12.6	23.6	25.1	33.7	34.0	32.3	45.8	43.6	57.8
Gabon	...	1.2	...	...	1.0	1.1	2.6	3.5	3.5
Gambia	...	...	...	...	1.0	2.5	3.2	3.4	4.3
Germany (East)	-	-	-	-	-	-	0.2	0.5	0.5
Ghana (b)	30.9	34.5	42.7	56.8	73.1	66.5	74.5	103.1	94.1
Greece	-	14.5	17.0	18.6	21.0	27.1	30.1	32.0	27.1
Guinea	...	...	...	...	4.9	4.9	4.9	4.9	5.0
Ifni	...	∅	∅	∅	∅	∅	∅	∅	∅
Israel	-	...	...	...	2.0	2.1	1.5	4.0	3.1
Italy	5.9	11.8	17.7	22.8	37.6	57.8	64.7	69.4	62.8
Ivory Coast (c)	40.0	41.5	43.0	45.0	50.5	57.5	57.6	62.9	65.8
Japan (d)	...	28.9	73.3	104.5	95.9	159.4	128.7	169.5	166.8
Korea (Rep. of)	-	-	-	-	...	∅	7.1	11.1	12.6
Liberia ~~(e)~~	1.4	2.3	2.6	4.0	7.9	11.5	11.8	11.8	12.0
Mauritania	...	...	...	...	14.0	15.0	16.0	17.7	18.0
Morocco (f)	167.4	172.3	165.1	176.5	189.5	204.8	292.9	249.2	207.9
Nigeria (g)	...	35.5	35.7	43.2	55.4	58.0	60.0	58.5	58.5
Norway	-	-	-	-	-	-	0.5	1.2	0.6
Philippines	...	...	...	...	...	...	...	...	...
Poland	-	0.2	3.3	11.0	14.6	24.2	43.6	46.7	33.5
Portugal	43.8	52.8	48.3	47.6	47.4	45.8	41.4	39.8	40.0
Portuguese Guinea	0.5	0.7	0.6	0.6	0.8	0.9	0.7	0.7	1.3
Romania	-	-	-	-	3.0	4.9	7.1	8.8	5.5
São Tomé and Principe	0.6	0.7	0.6	0.5	0.8	0.9	0.8	0.9	0.8
Senegal	56.9	97.9	103.4	100.7	99.8	101.2	116.5	132.0	153.5
Sierra Leone	17.5	22.4	25.5	27.6	29.1	31.8	31.4	32.7	22.6
Spain	...	...	...	...	155.0	167.1	181.4	179.4	178.3
Spanish Sahara	2.2	5.7	4.8	2.0	2.3	4.8	3.8	3.9	3.9
Togo	1.9	...	2.8	1.7	3.0	3.5	4.5	5.0	5.0
USSR	...	...	...	147.1	163.9	82.4	79.3	153.5	318.6
TOTAL (h)	390.0	570.0	640.0	880.0	1,140.0	1,200.0	1,340.0	1,490.0	1,620.0

Notes - ... No data
- Information zero
Denotes catches less than 100 tons
Data refer to quantities sold through principal markets only
Excluding catches by chartered foreign vessels
Includes estimates for catch in brackish waters (6,000 metric tons in 1966 and 1967) and for artisanal marine fisheries (10,000 metric tons in 1966 and 1967)
1965-7, includes catches in the Southeast Atlantic
Includes landings by chartered foreign trawlers
Data refer to the Atlantic fisheries only, the Mediterranean catch is excluded
Data include quantities caught by chartered Japanese, Russian and Polish fishing craft
Total includes estimates for the catch data of countries where "..." indicate that no official figures are available to FAO. Total is rounded to the nearest ten thousand metric tons

Appendix Table F2 - Catches in the Eastern Central Atlantic by group of species and by species

GROUP OF SPECIES Species	1958	1962	1963	1964	1965	1966	1967	1968
FLOUNDERS, HALIBUTS, SOLES, etc.	1.0	3.0	5.0	3.0	5.0	5.0	4.0	6.0
TOTAL	1.0	3.0	5.0	3.0	5.0	5.0	4.0	6.0
CODS, HAKES, HADDOCKS, etc.								
Hakes	12.8	6.9	5.1	8.9	13.7	17.0	27.4	19.6
TOTAL	13.0	10.0	8.0	12.0	16.0	22.0	32.0	24.0
REDFISHES, BASSES, CONGERS, etc.								
Croakers	6.8	21.4	16.1	14.2	19.0	21.5	11.7	17.6
Grunters, grunts	8.4	22.8	13.8	8.6	19.9	17.1	8.7	8.1
Sea-basses, sea-perches, groupers	7.0	10.1	9.9	8.2	10.7	11.2	8.7	8.9
Sea-breams, porgies	54.5	133.9	123.4	136.3	89.3	80.6	88.4	91.0
TOTAL	92.0	246.0	219.0	216.0	189.0	174.0	173.0	195.0
JACKS, MULLETS, etc.								
Horse mackerels, jack mackerels, mackerel scad	3.1	39.9	47.9	53.6	47.3	35.2	92.1	156.0
TOTAL	15.0	56.0	64.0	75.0	71.0	75.0	118.0	198.0
HERRINGS, SARDINES, ANCHOVIES, etc.								
Bonga	9.0	13.5	15.0	16.5	19.0	23.0	24.0	16.0
European pilchard (=sardine)	124.1	130.6	131.6	147.0	160.0	266.2	232.7	200.6
Round and flat sardinellas	64.1	73.2	79.3	120.7	90.0	87.0	138.1	124.5
TOTAL	198.0	219.0	226.0	285.0	280.0	377.0	396.0	342.0
TUNAS, BONITOS, SKIPJACKS	66.0	77.0	98.0	99.0	106.0	105.0	118.0	163.0
TOTAL	66.0	77.0	98.0	99.0	106.0	105.0	118.0	163.0
MACKERELS, BILLFISHES, CUTLASS-FISHES, etc.	11.0	59.0	50.0	77.0	42.0	41.0	79.0	136.0
TOTAL	11.0	59.0	50.0	77.0	42.0	41.0	79.0	136.0
SHARKS, RAYS, CHIMAERAS	3.0	4.0	8.0	10.0	13.0	14.0	7.0	10.0
TOTAL	3.0	4.0	8.0	10.0	13.0	14.0	7.0	10.0
UNSORTED & UNIDENTIFIED FISHES				307.0	343.0	409.0	400.0	379.0
TOTAL				307.0	343.0	409.0	400.0	379.0
CRUSTACEANS	4.0	6.0	5.0	5.0	6.0	5.0	6.0	6.0
TOTAL	4.0	6.0	5.0	5.0	6.0	5.0	6.0	6.0
MOLLUSCS								
Squids	0.1	0.2	0.3	6.8	13.9	11.8	14.3	13.7
Cuttlefishes	11.5	13.8	24.9	25.8	40.1	37.2	42.9	40.5
Octopuses	0.9	1.0	1.9	18.9	69.2	61.7	96.4	96.7
TOTAL	13.0	15.0	28.0	53.0	133.0	124.0	165.0	159.0

Appendix Table G1 - Total landings from the Western Central Atlantic by countries ('000 tons, live weight)

Country	1958	1961	1962	1963	1964	1965	1966	1967	1968
Barbados	4.5	4.6	4.7	2.8	2.1	2.6	4.8	4.6	3.5
Colombia	(6.0)	22.3	23.1	19.5	22.6	24.5	28.8	45.9	60.1
Cuba	21.9	30.5	35.0	35.6	36.3	40.4	43.2	63.3	63.5
Guyana	3.5	7.4	7.9	9.2	10.4	12.0	12.3	13.9	16.0
Jamaica	7.8	11.5	11.9	13.9	16.0	16.6	16.9	17.2	...
Japan (tuna)	...	1.4	16.9	30.9	35.4	29.5	20.2	6.5	...
Mexico	(45.0)	(60.0)	(60.0)	64.1	72.5	82.0	(80.0)	87.1	98.9
Trinidad and Tobago	4.2	7.7	7.5	7.7	9.7	10.5	9.1	12.4	12.8
USSR (a)	-	...	...	...	39.9	50.5	37.4	23.9	6.8
USA (a) (b)	(330.1)	(795.9)	(778.9)	1,645.7	1,604.0	1,730.6	865.1	868.3	...
Venezuela	68.1	70.5	81.5	84.1	91.2	102.7	98.4	912.4	103.7
Others	42.0	31.0	26.0	37.0	41.0	44.0	49.0	44.0	
TOTAL*	735.0	1,045.0	1,055.0	1,950.0	1,980.0	2,145.0	1,265.0	2,100.0	365.0

Notes - (a) Live weight

(b) Up to 1962, molluscs without shells

... No data

- Information zero

* Total is rounded to the nearest five thousand tons

Brackets denote approximation

Appendix Table G2 - Catches by major species groups from the Western Central Atlantic ('000 tons, live weight)

Species/Species group	1958	1961	1962	1963	1964	1965	1966	1967	1968
Anadromous									
Alewife	6.8	5.5	6.9	7.2	3.6	7.3			
Redfishes, basses, congers, etc.									
Croakers (Sciaenidae)	18.2	18.0	16.9	17.9	18.0	20.1			
USA	15.3	11.7	10.8	10.5	10.7	10.6			
Grunts (Pomadasyidae)	3.4	4.3	6.0	6.7	6.6	5.8	23.4		
Catfish (Ariidae)	1.6	2.0	5.3	4.9	5.4	6.0	(6.5)		
Sea-basses (Serranadae)	...	(19.0)	(19.0)	18.1	19.5	21.7			
Snappers (Lutjanidae)		(17.0)	(18.0)	17.2	18.2	16.7			
Various demersal percoids	7.0	(10.0)	(12.0)	12.1	26.7	27.7	(27.0)		
Jack, mullets									
Mullets	(27.0)	(28.0)	28.0	29.3	28.0	28.3			
Various carrangids	9.3	7.5	9.3	9.1	9.7	9.9			
Herrings, sardines, anchovies									
Menhaden	311.6	578.3	550.6	536.9	496.4	551.2	457.2	405.0	459.5
Various clupeoids	33.9	36.2	42.8	43.8	48.9	55.7	53.3		
Tunas									
Yellowfin		(17.0)	(17.6)	(24.8)	12.9	8.5	13.1	7.3	4.9
Various	6.6	12.3	9.2	8.3	7.8	8.3	7.3	7.8	7.0
Mackerels, billfishes									
King mackerels	(13.0)	(13.0)	(14.0)	14.1	13.4	15.6			
Others	1.0	1.0	1.1	1.3	1.7	2.2	2.1		
Sharks and rays	2.4	2.5	4.9	5.4	5.7	5.8	5.9		
Unsorted fish	...	...	...	...	...	...	...		
Crustaceans									
Blue crab	26.4	34.6	29.5	35.3	35.2	36.9	26.9	25.5	19.6
Prawns and shrimps				126.4	122.3	135.6			
USA	88.9	69.6	76.1	99.2	89.1	100.4	92.8	114.9	108.6
Mexico	...	...	...	17.8	20.2	20.3	...	21.8	23.1
Guyana	...	1.8	2.3	2.8	3.2	3.7	4.3	4.1	4.2
Venezuela	1.1	2.5	3.8	3.9	4.3	7.5	3.4	5.1	4.6
Spiny lobsters	...	9.6	9.0	9.3	8.6	13.1	(13.0)		
Various	1.6	1.7	1.7	3.3	(5.5)	(5.5)	(6.0)		
Molluscs									
Cephalopods	...	...	...	1.4	1.2	1.1	...		

Notes - ... No data

Brackets denote approximation

Appendix Table H1 - Catches from the Indian Ocean ('000 metric tons)

Country	1961	1962	1963	1964	1965	1966	1967	1968
South Africa (a)	3	3	3	3	3	3	3	3
Mozambique	3	3	4	4	4	5	5	...
Madagascar	4	4	5	6	8	17	16	17
Tanzania	16	17	19	20	22	29	29	22
Kenya	5	5	5	5	6	7	6	6
Somalia	4	4	4	...	...	...	...	...
Ethiopia	17	14	9	12	15	13	11	...
UAR	...	25	24	18	15	...	...	...
Saudi Arabia	16	18	20	20	19	20	22	28
Southern Yemen	47	54	55	52	52	50	40	46
Muscat, Oman (a)	100	100	100	100	100	100	100	100
Iran	...	...	...	...	...	17	17	...
Pakistan (West)	67	73	76	88	98	131	129	130
India (West coast)	521	487	492	672	649	682	654	671
Maldives	...	...	12	12	20	22	25	24
Ceylon	71	79	88	96	87	97	106	135
India (East coast)	163	157	164	188	175	208	209	233
Pakistan (East)	36	35	42	46	44	44	51	52
Thailand	23	27	32	22	16	30	114	162
Indonesia	105	109	112	118	133	144	136	145
Australia	13	14	14	14	13	16	18	19
Japan	5	127	100	81	91	87	131	...
China (Taiwan)	8	8	9	9	7	4	14	37
Korea	-	-	-	-	-	1	4	12
USSR	-	...	2	5	36	76	38	10
TOTAL (b)	1,530	1,660	1,680	1,910	1,950	2,140		

Notes - (a) Estimates
(b) Includes catches by countries not listed separately
... No data
- Information zero

Appendix Table H2 - Catches of major species and species groups from the Indian Ocean ('000 metric tons)

Species	1962	1963	1964	1965	1966	1967	1968
Salmonids	1	6	7	6	6	3	3
Milkfishes, etc.	15	15	17	18	19	16	13
Flatfish	18	10	7	11	9	8	12
Gadoids	3	7	5	7	5	4	3
Basses, croakers, etc.	257	257	266	270	322		
Bombay Duck (India)	84	92	81	74	77	75	82
Jacks, mullets, etc.	50	54	64	50	69		
Sardines, anchovies	271	215	452	439	428		
Oil sardine (India)	110	64	274	262	253	259	301
" " (Pakistan)	5	6	7	8	9	10	10
Tunas	144	142	115	138	133		
Mackerels	81	126	84	120	116		
Rastrelliger (India)	29	77	24	43	32	29	21
" (Thailand)							
Elasmobranchs	80	86	82	82	93		
Unsorted and unidentified fish	616	638	662	683	795		
Crustaceans	120	121	146	125	144		
Shrimps (India)	83	82	95	77	91	92	100
" (Pakistan)	14	14	21	22	22	25	23
Molluscs	1	1	3	2	3		

Appendix Table I1 - Catches from the Western Central Pacific ('000 tons)

Country	1962	1963	1964	1965	1966	1967	1968
Japan (a)	3,719	3,690	3,274	3,567	3,795	3,476	...
Republic of Korea	328	368	418	442	478	500	558
North Korea (b)	(550)	(550)	(550)	(550)	(550)	(550)	(550)
Ryukyu	15	17	22	24	25	29	35
China (Mainland) (b)	(2,750)	(2,750)	(2,750)	(2,750)	(2,750)	(2,750)	(2,750)
China (Taiwan)	282	305	324	326	368	384	414
Hong Kong	59	61	54	55	53	58	71
Vietnam (North) (b)	222	214	(215)	(215)	(215)	(215)	(215)
Vietnam (South)	200	329	345	318	316	351	359
Cambodia	31	36	39	43	39	35	46
Thailand	249	303	472	513	391	648	842
Malaysia	328	368	418	442	477	500	558
Singapore	11	12	10	11	18	18	17
Philippines	429	486	543	605	645	688	791
Brunei	2	4	3	4	3	1	2
Indonesia	436	447	472	532	576	542	581
New Guinea	7	10	10	13	13	13	14
USSR	-	-	-	-	-	-	53

Notes - (a) The division of the catches of Japan between the North Pacific and the Western Central Pacific has been estimated (see also Appendix Table D1)

(b) Catches of North Korea and Mainland China are very rough estimates

... No data

Brackets denote estimation

The precise figures of the catches of several other countries should be treated with some caution (see text)

Appendix Table J1 - Total fish catches from the Eastern Central Pacific ('000 metric tons)

	1962	1963	1964	1965	1966	1967	1968
A. Commercial landings							
USA	235	232	226	209	204	225	...
Mexico	153	174	172	170	199	253	257
Guatemala	1	2	2	2	3	2	1
El Salvador	7	7	7	7	9	8	11
Nicaragua	ø	ø	ø	ø	1	1	1
Costa Rica	1	1	2	3	3	3	5
Panama	14	13	26	39	72	72	72
Colombia	3	3	2	3	3	23	25
Ecuador	43	50	46	53	48	50	47
USSR	...	...	...	...	...	...	...
TOTAL	457	482	483	486	542	637	
B. Shrimp by-catch							
Mexico	250-500	270-540	245-490	195-390	200-400	240-480	
El Salvador	30-60	30-60	30-60	25-50	35-70	25-50	
Panama	25-50	25-50	35-70	30-60	30-60	30-60	
Others	45-90	50-100	50-100	55-110	50-100	60-120	
C. Sports fishermen							
USA				50			
TOTAL, all catches	807-1,157	858-1,233	844-1,204	789-1,094	862-1,177	1,061-1,416	

Notes - ... No data
ø Denotes catches less than 100 tons

Appendix Table J2 - Catches of major species from Eastern Central Pacific ('000 tons)

Species group	Country	1962	1963	1964	1965	1966	1967	1968
Flounders	USA	7	10	9	10	10	5(e)	
Hake	USSR						35	
Rock fishes	USSR						17	
	USA (commercial)	4	5	4	4	5	5	
Various demersal fish	USA	1	1	2	2	2	2(e)	
	USSR						10	
Jack mackerel	USA(b)	41	44	41	30	19	17	
North Pacific anchovy	USA(b)	1	2	2	3	28	32	
	Mexico(a)	1	2	5	9	14	22	
California sardine	USA	7	3	6	1	+	+	
	Mexico(c)	15	19	19	20	19	29	
Various clupeoids	Panama	9	7	18	33	66	65	65
Tuna (all Pacific landings)	Mexico	4	4	4	4	5	9	
	Ecuador	11	13	10	15	12	20	
	USA - yellowfin	56	50	68	72	60	64	
	USA - skipjack	46	48	34	46	27	54	
	USA - others	36	44	34	27	42	38	
Mackerel	USA	22	18	12	3	2	1(e)	
Squid	USA	4	5	7	8	9	9(e)	
Shrimp	Mexico	50	54	49	39	40	48	
	El Salvador	6	6	6	5	7	6	4
	Panama	6	6	7	6	6	6	6
Molluscs	Mexico	10	11	10	12	11	11	
TOTAL, specified fisheries		337	352	347	345	384	505	
TOTAL, all landings (d)		457	483	484	484	547	706	

Notes - (a) All anchovies
(b) All US Pacific coast
(c) Includes various clupeoids
(d) Excluding shrimp by-catch
(e) Preliminary

Appendix Table K1 - Catches from the Southwest Pacific, 1962-8 ('000 tons)

Country	1962	1963	1964	1965	1966	1967	1968
Australia	52	56	62	66	72	74	82
New Zealand	41	41	44	48	56	60	60
French Polynesia	4	5	4	5	(5)	(5)	(5)
New Hebrides	4	3	3	3	4	4	4
Papua	(3)	(5)	(5)	(7)	(7)	(7)	(7)
Japan (tuna)	75	85	63	56	69	86	...
(trawl)	3	3	2	4	3	1	...
(bottom longline)	...	∅	...	6	...	...	...
China (Taiwan) (tuna)	-	-	1	5	7	11	12
Korea (tuna)	1	2	2	8	18	20	19

Notes - ... No data

∅ Denotes catches less than 100 tons

Brackets denote approximation

Appendix Table K2 - Catches of major species by Australia and New Zealand from the Southwest Pacific ('000 tons)

Country	Species	1963	1964	1965	1966	1967	1968
Australia (a)	Flatheads	3.1	2.8	3.1	2.6	2.7	2.4
	Morwong	2.2	2.0	1.5	1.4	1.7	1.4
	Whitings (sillago)	1.7	1.6	1.7	1.6	1.6	1.7
	Australian salmon	3.0	4.4	3.2	4.1	5.3	5.4
	Mullets	6.2	5.7	5.5	6.4	5.7	5.3
	Barracouta (snoek)	1.6	1.4	2.2	2.8	1.7	3.2
	Tunas	5.0	8.1	7.2	8.1	5.6	6.8
	Prawns	5.7	6.1	5.5	5.7	6.2	9.1
	Rock lobsters	14.3	12.5	12.0	13.6	14.4	15.1
	Abalone	-	0.1	0.4	1.4	4.9	8.5
	Oysters	5.9	5.8	6.6	6.8	7.3	7.6
	Scallops	2.9	7.0	11.2	13.4	13.6	13.7
TOTAL		70.8	76.6	79.4	88.7	92.0	102.7
New Zealand	Snapper	8.4	8.2	8.6	10.4	10.5	
	Tarakihi	5.7	5.9	6.0	6.2	6.3	
	Trevally	2.4	2.4	2.6	3.1	3.1	
	Rock lobsters	4.5	4.6	5.0	6.6	8.1	
	Oysters, dredged	5.9	7.5	9.7	12.7	13.1	
TOTAL		40.8	44.2	48.4	55.7	59.6	

Note - (a) Australian figures include catches by all waters and not only from the Southwest Pacific

Appendix Table L1 - Catches by countries in the Southeast Pacific (including crustaceans and molluscs) ('000 tons) (a)

	1958	1963	1964	1965	1966	1967	1968
Peru	961	6,899	9,116	7,462	8,789	10,134	10,520
Chile	226	762	1,161	709	1,384	1,053	1,376
TOTAL	1,187	7,661	10,277	8,171	10,173	11,187	11,896

Notes - (a) Excludes small quantities of tuna taken offshore by long-range vessles

Appendix Table L2 - Catches of major species in the Southeast Pacific

Species	Country	1958	1963	1964	1965	1966	1967	1968
Anchoveta	Chile	40	539	934	438	1,091	705	1,009
	Peru	737	6,635	8,863	7,242	8,530	9,825	10,263
Hake	Chile	75	102	73	106	94	80	128
	Peru	-	-	-	-	-	20	18
Bonito	Chile	4	2	6	11	13	9	4
	Peru	66	91	81	62	71	64	54
Shrimp	Chile	1	4	6	6	11	10	10
Squat lobsters (langostina)	Chile	13	9	11	15	13	20	18
Mussels	Chile	21	21	24	20	23	30	23

Appendix Table M1 - Total catches of marine animals from the Southwest Atlantic ('000 tons)

Country	1961	1962	1963	1964	1965	1966	1967	1968
Argentina	88	91	118	154	192	241	228	212
Brazil	215	313	333	238	278	306	328	344
Uruguay	9	8	8	12	16	12	11	12
China (Taiwan) (a)	-	-	-	-	-	-	-	1
Cuba	-	-	-	-	-	+	2	2
Japan (a)	...	...	22	21	32	14	14	10
USSR	-	-	-	-	-	73	678	190
Germany (Fed.Rep of)	-	-	-	-	-	-	2	-
Germany (East)	-	-	-	-	-	+	+	1
TOTAL	318	414	481	425	518	646	1,263	771

Notes - (a) Mainly tuna
... No data
- Information zero

Appendix Table M2 - Catches of major species and species groups from the Southwest Atlantic

Species	Country	1961	1962	1963	1964	1965	1966	1967	1968
Hake	Argentina	34	38	52	71	77	68	76	72
	Brazil	3	19	11	19	18	18	6	...
	Uruguay	2	2	3	6	8	4	3	...
	USSR	...	...	...	...	...	56	513	100
Croakers	Argentina	3	4	5	8	8	12	21	15
	Brazil	47	41	37	31	37	42	48	...
Hawkfish	Argentina	+	3	4	7	30	68	34	4
Mullets	Brazil	13	16	18	17	21	20	23	...
Round sardinella	Brazil	35	55	82	48	69	78	88	...
Anchovy	Argentina	11	8	12	17	17	11	13	32
	Brazil	7	4	4	4	5	2	3	...
Mackerel	Argentina	10	8	12	10	10	16	11	16
Shrimps	Brazil	25	25	28	28	39	35	35	...
Mussels	Chile	16	19	21	24	20	23	30	23

Note - ... No data

Appendix Table N1 - Summary of catches from the major fisheries in the Southeast Atlantic ('000 tons)

Species	Country	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Hake	Japan	-	-	-	-	6	19	32	44	84	...
	South Africa	104	115	95	94	91	92	87	109	112	119
	Spain				4	18	46	118	156	185	171
	USSR						2	82	135	104	332
TOTAL (c)		105	116	96	99	116	160	324	462	499	711
Sea breams	Japan(a)				10	18	27	8	13	9	...
Pilchard	South Africa	260	318	402	411	401	256	204	114	299	675
	Southwest Africa(b)	271	283	342	295	547	656	666	635	707	808
	USSR	-	-	4	6	25	79	111	52	42	10
	Angola	43	59	56	77	76	108	57	70	56	94
TOTAL (c)		574	660	804	889	1,049	1,101	1,041	875	1,106	1,588
Anchovy	South Africa	-	-	-	-	23	95	209	157	276	170
Maasbanker	South Africa	21	69	45	72	26	27	61	30	12	5
	Angola			103	88	75	157	131	185	168	137
	Japan				∅	2	7	5	2	3	...
Mackerel	South Africa	33	29	52	21	13	52	40	56	139	90
Rock Lobster	South Africa	9	9	9	9	8	8	8	8	8	7
	Southwest Africa	5	4	6	7	6	8	8	9	6	9

Notes - (a) Includes trawl catches from the area between Equator and 6°S
(b) Includes catches by South African factory vessels off Southwest Africa
(c) Includes catches by countries not listed
∅ Denotes catches less than 100 tons
... No data
- Information zero

Appendix Table N2 - Catches in the Southeast Atlantic by countries ('000 metric tons)

Country	1958	1961	1962	1963	1964	1965	1966	1967	1968
Angola	278.2	241.5	269.3	239.7	355.8	256.7	327.5	292.1	293.4
China (Taiwan)	-	-	0.3	0.5	0.5	...	0.4	3.9	11.3
Germany (East)	-	-	-	-	-	...	1.4	...	...
Germany (Fed.Rep. of)	-	-	-	-	-	...	11.3	12.9	3.6
Israel	-	...	...	...	...	1.7	8.1	3.9	7.4
Italy	-	-	-	-	-	...	...	...	...
Japan (trawl)	-	-	11.1	27.9	55.6	54.2	72.9	117.2	...
Korea (Rep. of)	-	-	-	-	...	...	...	...	...
Poland	-	-	-	...	...	...	...	...	...
Romania	-	-	-	-	...	...	...	...	...
South Africa	415.5	654.5	653.0	610.5	582.9	660.6	529.0	902.4	1,130.2
Southwest Africa	236.9	352.9	405.1	556.9	669.0	678.5	650.0	740.2	982.7
Spain	-	-	6.2	23.9	52.7	132.9	195.1	231.2	243.7
USSR	...	...	...	49.5	166.8	360.7	361.1	251.1	484.5

Notes - ... No data
- Information zero

Appendix Table P1 - World catches of whales from Oceanic Resources (numbers of animals)

Species	Country	1935	1950	1955	1960	1965	1966	1967	1968
Blue	Antarctic	16,500	6,163	2,163	112	20	1	4	-
TOTAL				2,495	1,465	613	243	70	-
Fin	Antarctic	12,500	18,061	25,878	26,415	7,308	2,318	2,893	2,155
TOTAL				32,185	30,985	12,317	6,882	6,342	5,268
Sei	Antarctic	266	101	146	3,234	19,874	17,583	12,368	10,357
TOTAL				1,940	7,035	25,453	23,067	18,990	16,690
Humpback	Antarctic	1,965	2,117	493	1,338	-	1	-	-
TOTAL				2,713	3,576	452	59	4	2
Sperm				15,593	20,344	25,548	27,378	25,921	24,073
TOTAL				15,593	20,344	25,548	27,378	25,921	24,073
Minke	Norway			4,328	3,429	2,467	2,153	2,175	
TOTAL				4,768	3,944	2,917	2,932	3,033	
Bottlenose	Norway			124	193	692	340	264	
TOTAL				124	211	700	341	271	
Pilot whales	Faroes				1,680	1,599	1,488	1,979	
	Newfoundland			6,612	1,957	1,520	887	739	
TOTAL					4,136	3,633	2,915	3,072	
Killer whales				123	230	275	311	143	
TOTAL				123	230	275	311	143	
White whales				581	385	1,120	1,022	960	
TOTAL				581	385	1,120	1,022	960	
Various small whales				301	365	1,787	435		
TOTAL				301	365	1,787	435		

Notes - Source: International Whaling Commission statistics

For the Antarctic, the year 1967 means catches in the season 1966/7, etc.

- Information zero

Appendix Table P2 - World catches of tuna from Oceanic Resources ('000 tons)

Species	Country	1958	1963	1964	1965	1966	1967	1968
Albacore	France	21	17	21	17	14	17	15
	Japan	63	116	117	127	106	98	70
	Spain	29	28	17	29	26	32	24
	USA	17	28	22	17	17	22	25
TOTAL		144	206	194	214	190	210	192
Bigeye	Japan	73	130	112	110	106	106	96
TOTAL		77	134	117	115	112	115	114
Bluefin	Japan	21	63	61	56	45	55	57
TOTAL		82	118	114	101	99	101	101
Yellowfin	France	12	27	26	24	33	31	49
	Japan	112	131	124	124	128	94	116
	USA	57	50	68	72	60	64	70
TOTAL		200	247	252	246	258	230	302
Billfishes	Japan	45	63	66	70	60	55	51
TOTAL		54	75	78	81	72	69	69
Swordfish		21	32	34	32	33	33	33
TOTAL		21	32	34	32	33	33	33
Skipjack	Ecuador	12	14	10	14	11	17	14
	Japan	147	113	167	136	229	182	169
	Peru	13	17	7	8	6	14	6
	USA	59	49	35	46	27	54	31
TOTAL		241	205	230	215	288	288	253
Bonito	Peru	66	91	81	62	71	64	54
	Turkey	19	19	11	21	16	34	21
TOTAL		132	145	139	133	158	131	124
Frigate mackerel	Japan	23	48	27	31	30	29	23
TOTAL		36	57	35	40	37	39	31
Little tuna		4	4	2	4	3	4	3
TOTAL		4	4	2	4	3	4	3
Various	Ceylon	10	32	23	26	30	43	56
	China (Taiwan)	...	15	18	13	16	22	22
	Japan	...	14	14	13	13	15	14
	Korea	+	3	3	9	26	38	44
	Spain	+	7	11	16	32	23	32
TOTAL		70	135	138	150	206	244	285
TOTAL (all species including bill-fishes and sword-fishes)		1,061	1,358	1,333	1,331	1,456	1,464	1,507

Note - ... No data

Appendix Table Q1 - Landings of molluscs (excluding cephalopods) by species groups ('000 tons)

	1958	1961	1962	1963	1964	1965	1966	1967	1968
Gastropods									
Northeast Atlantic									
Ireland	1.9	2.1	2.1	1.8	1.7	1.7	2.3	2.0	2.3
N. Ireland	ø	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.2
Scotland	0.9	0.9	0.8	0.9	1.0	1.0	1.2	1.0	1.0
England	2.1	1.9	2.0	2.0	2.1	2.2	2.4	2.4	2.4
Netherlands	0.3	0.4	0.3	0.2	0.3	0.3	0.2	0.2	0.1
Belgium	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.3
Spain (a)	0.1	0.1	0.3	0.3	0.4	0.4	0.3	0.3	0.3
Northwest and Western Central Atlantic									
USA	1.3	0.9	1.1	1.7	1.1	1.0	1.9	1.3	1.1
Canada	-	-	-	-	-	1.0	ø		
Southeast and Eastern Central Atlantic									
S. Africa	0.5	1.4	1.7	1.7	1.7	1.7	0.7	0.7	0.6
Southwest Atlantic									
Argentina	ø	ø	ø	ø	ø	ø	ø	ø	ø
Northeast Pacific									
Canada	ø	ø	ø	ø	0.1	ø	ø	ø	ø
USA	1.9	2.1	1.9	2.0	1.8	2.0	2.2	2.0	2.0
Mexico (a)	17.2	6.4	7.1	8.3	7.6	7.8	6.7	6.4	8.2
West Pacific									
Japan	10.0	8.5	9.5	9.5	11.8	11.2	12.5	13.2	14.0
Korea (Aquiculture)	...	ø	1.5	ø	0.6	-	-	-	...
Korea (Marine fisheries)	1.1	1.5	1.5	1.9	2.4	3.1	5.4	3.2	3.4
China (Taiwan)	ø	ø	ø	ø	ø	ø	ø	ø	ø
Malaysia (a)	-	1.1	0.9	1.3	1.2	1.0	0.5	0.4	0.5
Southeast Pacific									
Peru	ø	0.2	ø	0.2	0.2	0.2	0.1	0.3	0.1
Chile	4.9	2.3	3.0	4.5	4.4	3.6	3.4	4.1	4.6
Southwest Pacific									
Australia	-	-	-	-	0.1	0.4	1.4	4.9	8.5
Scallops									
Northeast Atlantic									
Ireland	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
N. Ireland	...	ø	0.1	0.2	0.4	0.2	0.1	ø	ø
Scotland	0.1	0.2	0.3	0.6	0.5	0.4	0.6	1.0	2.7
England	ø	ø	0.1	0.1	0.1	0.1	0.1	0.1	0.2
France (a)	3.6	6.2	6.9	7.1	8.2	7.5	6.9	7.4	8.4
Spain (a)	0.1	0.2	0.2	0.2	0.2	0.6	0.7	0.2	0.2
Northwest Atlantic									
Canada	12.0	38.4	48.8	58.9	60.6	71.6	66.3	48.4	56.8
USA	79.5	109.6	103.9	80.5	70.4	89.8	80.4	54.9	60.0
Southwest Atlantic									
Argentina	-	-	0.1	0.6	0.8	0.4	0.2	0.6	1.1

	1958	1961	1962	1963	1964	1965	1966	1967	1968
West Pacific									
Japan	19.6	10.7	10.1	9.0	6.9	5.7	7.4	6.8	5.0
China (Taiwan)	0.1	0	0.1	0	0	0	0	0	0
Southwest Pacific									
Australia	1.9	3.1	2.3	2.9	7.0	11.2	13.4	13.6	13.7
Clams									
Northeast Atlantic									
Scotland	-	-	0	0.1	0.2	0	-	0	-
England	5.5	8.3	9.5	6.4	5.4	7.1	9.5	15.5	13.3
Netherlands	0.6	0.1	7.1	2.4	6.4	8.4	11.4	1.9	0.3
Spain (a)	9.6	12.0	19.9	18.3	25.6	30.0	29.8	41.1	44.4
Portugal	1.9	1.1	1.4	1.2	2.1	1.7	1.5	1.1	...
Northwest and Western Central Atlantic									
Canada	2.3	1.7	1.7	1.3	1.6	1.8	2.2	2.3	2.7
USA	104.6	130.7	136.4	164.5	168.6	182.9	186.6	183.7	168.8
Cuba	...	0	0	0	0	...	...	...	...
Southwest Atlantic									
Brazil (b)	2.1	2.2	2.0	1.6	2.5	2.4	1.8	4.4	...
Northeast Pacific									
Canada	1.1	1.1	1.8	1.4	0.7	1.0	1.0	1.3	0.7
USA	1.6	1.4	1.4	1.1	0.8	1.0	0.9	0.8	0.7
Mexico (a)	1.6	2.2	2.0	1.0	0.7	0.9	0.8	1.9	1.3
West Pacific									
Japan	170.2	157.7	158.3	203.5	171.8	171.7	194.7	173.4	169.0
Korea (Aquiculture)	0.9	6.9	3.3	11.4	17.3	15.6	20.4	25.8	...
Korea (Marine fisheries)	2.3	3.2	3.6	2.3	10.9	1.9	3.8	3.7	8.8
China	1.7	1.6	1.4	1.5	1.5	1.4	1.4	1.5	2.0
Malaysia (a)	8.5	6.0	8.0	19.6	19.3	19.4	24.5	26.9	27.0
Southeast Pacific									
Chile (c)	3.8	3.7	4.4	5.2	9.1	9.3	8.7	8.6	14.7
Mussels									
Northeast Atlantic									
Ireland	2.4	0.8	0.3	0.9	0.9	0.9	0.8	1.2	2.4
Scotland	0.6	0.6	0.6	0.9	0.8	0.5	0.5	0.5	0.4
England	2.9	3.2	3.1	2.8	2.6	2.4	3.2	4.3	3.7
Norway	0	0.1	0.1	-	-	-	-	-	-
Sweden	0.5	0.5	0.8	0.4	0.6	0.6	0.7	0.5	...
Denmark	12.8	11.3	18.4	13.6	16.4	18.3	19.2	16.4	14.4
Germany	9.9	10.0	5.8	4.8	5.3	7.6	11.5	11.3	11.4
Netherlands	75.6	85.4	96.5	89.7	115.8	110.5	92.4	85.6	113.6
Belgium	0.2	0	0	0	0.1	0.1	0.1	0	0
France (a)	4.3	26.0	26.4	33.6	30.6	37.5	30.3	35.2	28.2
Spain (a)	4.9	36.7	56.0	63.4	63.5	66.3	64.3	50.5	68.7
Portugal	0	0	0	0	0.1	0.2	0.1	0.1	...
Northwest and Western Central Atlantic									
Canada	...	...	...	...	...	...	...	...	...
USA	1.3	2.0	1.9	2.5	0.9	1.3	1.4	2.1	2.7
Venezuela	0.1	0.1	0.2	0.2	0.2	0.1	0.3	0.2	0.3

	1958	1961	1962	1963	1964	1965	1966	1967	1968
Southwest Atlantic									
Uruguay	...	0.7	0.5	0.5	0.5	0.7	0.6	0.5	...
Argentina	2.1	5.0	5.0	5.2	6.5	6.9	6.2	6.3	8.1
Mediterranean									
Italy	17.1	17.5	19.6	22.4	19.6	16.0	12.9	16.1	14.0
Northeast Pacific									
Mexico (a)	...	...	...	ø	ø	ø	ø	0.2	0.4
West Pacific									
Korea (Aquiculture)	0.2	0.3	0.2	0.4	1.0	0.3	2.0	2.0	2.6
Korea (Marine fisheries)	3.1	2.1	2.9	2.7	3.3	2.6	2.7	3.3	3.3
China (Taiwan)	0.1	0.1	0.1	0.1	0.1	ø	ø		
Southeast Pacific									
Peru	1.9	3.2	3.8	3.0	3.6	3.9	4.4	5.5	5.3
Chile	21.1	15.8	19.3	21.1	24.0	20.4	22.7	29.6	22.7
Southwest Pacific									
Australia	-	0.2	0.3	0.3	0.2	0.2	0.2	0.1	0.1
New Zealand	2.6	2.8	2.4	1.7	1.7	2.2	2.1	1.6	2.1
Oysters									
Northeast Atlantic									
Ireland	ø	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.2
Scotland	-	-	ø	ø	ø	ø	-	-	ø
England	0.3	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.3
Norway	ø	ø	ø	-	-	-	-	-	-
Sweden	ø	0.1	ø	ø	0.1	ø	ø	ø	...
Germany	ø	ø	ø	ø	ø	ø	-	ø	ø
Netherlands	1.9	2.6	2.2	0.5	0.6	0.7	0.7	0.8	0.8
France (a)	13.2	87.1	76.5	70.3	62.2	65.8	62.3	69.5	44.7
Spain (a)	0.6	0.8	0.5	0.5	1.1	0.9	0.7	0.9	1.0
Portugal	0.9	ø	2.3	0.9	10.2	0.2	0.3	4.8	...
Northwest and Western Central Atlantic									
Canada	1.3	1.8	1.5	1.9	1.7	1.6	1.6	1.3	1.4
USA	384.2	361.8	321.7	355.1	374.1	313.6	324.9	384.0	360.0
Cuba	0.5	1.6	2.5	1.7	2.4	2.7	2.8	3.2	2.3
Venezuela	...	ø	0.1	ø	0.6	0.2	0.9	0.1	0.3
Trinidad	-	-	-	0.1	...	...	...	...	...
Southeast and Eastern Central Atlantic									
Senegal	0.1	0.1	0.2	0.6	0.5	0.6	0.8	0.4	0.2
Southwest Atlantic									
Brasil	...	0.1	0.4	0.2	0.2	0.3	0.2	...	...
Northeast Pacific									
Canada	2.7	2.9	3.5	5.8	5.2	5.1	5.7	4.4	3.3
USA	42.5	40.8	43.2	39.9	40.4	37.3	31.5	31.3	28.7
Mexico (a)	13.1	19.2	18.3	19.8	24.0	29.6	25.1	28.4	35.5
West Pacific									
Japan	151.2	172.9	203.6	240.1	240.6	210.6	221.1	232.2	267.5
Korea (Aquiculture)	5.0	27.2	7.0	53.3	32.4	44.7	48.0	42.0	34.7
Korea (Marine fisheries)	2.0	7.7	4.2	3.5	10.2	1.2	3.7	2.4	3.5
China (Taiwan)	5.2	8.1	7.6	7.9	8.5	8.9	10.3	11.7	12.6

	1958	1961	1962	1963	1964	1965	1966	1967	1968
Southeast Pacific									
Peru	2.7	0.3	0.2	0.1	0.2	0.2	0.7	0.3	0.4
Chile	0.2	ø	ø	ø	ø	0.1	ø	ø	...
Southwest Pacific									
Australia	4.8	6.5	5.7	5.9	5.8	6.6	6.8	7.3	7.6
New Zealand	6.9	8.8	5.6	6.1	7.7	9.9	12.9	13.2	...
Various Marine Molluscs									
Northeast Atlantic									
Ireland	ø	ø	0.1	0.2	0.1	0.1	0.2	0.2	0.4
Belgium	0.3	0.1	0.1	ø	ø	ø	ø	ø	ø
France (a)	8.0	9.5	11.4	9.2	11.4	11.3	11.2	10.9	15.0
Spain (a)	1.0	0.6	0.3	0.4	0.3	0.5	1.4	2.0	1.3
Portugal	0.1	0.1	0.1	ø	ø	0.1	0.1	0.1	...
North and Western Central Atlantic									
Canada	0.1	0.2	0.1	0.3	0.5	0.4	0.5	0.1	0.3
Cuba	0.4	-	-	-	-	ø	...	...	ø
Virgin Island	...	0.2	0.1	0.1	0.1	0.2	0.2	...	...
Trinidad and Tobago	...	...	...	0.1	0.1	0.1	0.1	0.2	0.2
Panama (a)	ø	ø	...	0.2	0.1	0.1	ø	ø	ø
Colombia (a)	0.1	0.2	0.1	0.5	0.6	0.6	0.6	0.8	0.8
Venezuela	...	0.1	0.1	0.1	0.2	0.1	...	...	0.1
Southeast and Eastern Central Atlantic									
Morocco (a)	0.1	ø	...	...	0.1	...	...	0.1	0.7
Sierra Leone	...	ø	ø	0.2	0.1	0.1	0.1	0.3	0.3
Southwest Atlantic									
Brazil (d)	2.2	ø	ø	0.2	0.2	0.2	0.3	0.5	...
Mediterranean									
Italy	4.5	6.7	6.6	6.1	9.0	9.4	8.7	11.4	12.7
Yugoslavia	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.4	0.1
Greece	...	...	...	...	...	...	2.8	2.7	...
Turkey	ø	ø	0.1	0.2	0.2	0.3	0.4	...	...
Cyprus	...	...	...	0.1	0.1	0.1	0.1	0.1	0.1
Tunisia	...	...	...	1.1	1.2	1.7	0.9	...	...
Northeast and Eastern Central Pacific									
Mexico (a)	1.8	...	...	ø	ø	ø	0.1	0.1	0.2
Guatemala (a)	...	...	...	ø	ø	ø	ø	ø	ø
West Pacific									
Japan (Aquiculture)	ø	0.1	0.1	0.4	0.8	0.6	-	-	0.1
Japan (Marine fisheries)	80.8	120.7	98.4	109.7	96.8	104.6	110.8	104.2	97.0
Korea (Aquiculture)	-	-	ø	...	3.0	0.3	0.9	0.9	1.0
Korea (Marine fisheries)	12.9	6.6	11.6	7.8	20.0	16.5	19.8	37.8	10.8
Ryukyu Islands	...	0.1	ø	0.1	ø	ø	ø	ø	ø
China (Taiwan)	1.3	1.7	1.6	1.7	2.0	2.0	1.9	2.0	1.9
Vietnam	...	...	...	4.8	...	...	4.7	4.5	3.3
Cambodia	...	0.1	0.3	0.1	0.2	0.3	0.3	0.3	0.4
Thailand (a)	50.6	86.9	82.2	72.3	70.1	62.6	102.1	105.6	141.8
Malaysia (a)	...	...	...	0.4	0.4	0.4	0.4	0.4	0.4
Philippines (e)	3.7	2.9	6.0	6.8	7.6	10.0	11.4	9.9	17.9

	1958	1961	1962	1963	1964	1965	1966	1967	1968
Southeast Pacific									
Chile (f)	4.3	...	...	5.3	5.8	3.3	6.2	2.0	1.0

Notes - (a) Where a country borders on more than one sea area its catches have been arbitrarily assigned in total to one of these areas; the countries affected are:

France, Spain: Northeast Atlantic, not Mediterranean
Panama, Colombia: Atlantic/Caribbean, not Pacific
Morocco: Atlantic, not Mediterranean
Mexico, Guatemala: Pacific, not Atlantic (Caribbean)
Malaysia, Thailand: Pacific, not Indian Ocean

(b) Data include oysters

(c) 1966-8 excluding cockles

(d) Data include squids and octopuses

(e) Data refer to squids

(f) Data include squids

... No data

- Information zero

ø Denotes catches less than 100 tons

Appendix Table R1 - Catches of crustaceans by species and by countries ('000 metric tons, live weight)

Species	Country	1958	1963	1964	1965	1966	1967	1968
Sea-spiders, crabs, etc.		197.0	272.0	288.0	310.0	348.0	341.0	354.0
Blue crab		50.0	66.0	71.0	78.0	77.0	68.0	51.0
Dungeness crab		21.0	13.0	13.0	15.0	20.0	22.0	22.0
Edible crab		10.0	10.0	10.0	8.0	8.0	8.0	8.0
King crab		64.0	110.0	117.0	130.0	150.0	131.0	112.0
	USA (Pacific)	5.1	35.7	39.3	59.7	72.3	57.9	38.6
	Japan	28.2	31.6	31.8	25.9	31.0	30.3	30.0
	USSR	30.9	42.5	46.2	44.4	46.0	42.3	40.4
Other marine crabs		52.0	73.0	77.0	79.0	93.0	112.0	161.0
	Japan	30.9	39.6	41.9	37.7	40.7	55.9	88.0
Lobsters, rock lobsters, spiny lobsters, etc.		79.0	90.0	92.0	92.0	92.0	88.0	96.0
European lobster		4.0	3.0	6.0	4.0	3.0	3.0	3.0
Northern lobster		32.0	34.0	33.0	32.0	30.0	28.0	32.0
Spiny lobsters, rock lobster		43.0	53.0	53.0	56.0	59.0	57.0(a)	(61.0)
	Namibia	4.0	5.9	7.6	8.0	8.9	5.9	8.5
	South Africa	12.7	8.3	8.4	8.4	8.0	8.3	6.7
	Cuba	4.2	7.4	6.6	9.1	9.0	8.3	8.9
	Brasil	1.1	3.6	3.3	3.4	2.8	2.5	...
	Australia	10.0	14.3	12.5	12.0	13.6	14.4	15.1
	New Zealand	4.4	4.5	4.6	5.0	6.6	8.1	...
Squat-lobsters, nephrops, etc.		32.0	38.0	41.0	43.0	45.0	51.0	50.0
Squat-lobsters		13.0	9.0	11.0	15.0	13.0	20.0	18.0
Norway lobster		19.0	29.0	30.0	28.0	32.0	31.0	32.0
Shrimps, prawns, etc.		502.0	671.0	670.0	663.0	697.0	757.0	771.0
Common shrimp		49.0	73.0	57.0	51.0	60.0	45.0	50.0
	Germany (Fed.Rep.of)	29.4	42.4	28.8	28.3	38.4	24.4	33.1
	Netherlands	13.1	24.7	21.9	17.4	15.5	14.3	11.2
Deep-water prawn		13.0	26.0	23.0	25.0	21.0	22.0	23.0
Prawns and shrimps		440.0	572.0	590.0	587.0	616.0	690.0	698.0
	Mexico	50.2	72.0	69.0	59.1	65.8	70.1	58.6
	USA (Atlantic)	88.9	99.4	89.5	101.4	92.8	114.9	108.6
	USA (Pacific)	8.1	9.6	6.6	9.1	15.6	24.7	23.7
	Brasil	17.4	28.3	28.1	39.4	34.7	35.5	...
	China (Taiwan)	4.0	9.0	9.8	14.2	16.3	19.5	21.7
	India	86.7	81.6	94.9	77.3	90.9	91.6	99.8
	Japan	55.6	86.7	77.8	66.5	68.8	61.0	66.3
	Korea (Rep. of)	16.4	14.2	18.1	17.2	12.1	21.0	11.4
	Malaysia (West)	9.0	19.0	19.3	20.8	24.4	32.3	32.9
	Pakistan (b)	14.9	18.4	25.7	27.0	22.2	25.0	23.4
	Philippines (c)	13.7	20.3	21.5	22.9	26.3	24.0	21.5
	Thailand	10.3	23.3	29.5	35.2	45.3	61.7	75.0
Miscellaneous marine crustaceans		36.0	53.0	67.0	69.0	77.0	102.0	106.0
TOTAL, all crustaceans		860.0	1,140.0	1,170.0	1,190.0	1,280.0	1,360.0	1,400.0

Notes - (a) In the computation of this total, more than 10% was estimated by FAO
(b) 1958, 1963-5, "Prawns and shrimps" includes "Freshwater crustaceans"
(c) Up to 1966, "Prawns and shrimps" includes "Other marine crabs"
... No data
Brackets denote estimation

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